NASA-TM-109851

National Facilities Study

Summary Report

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National Facilities Study

Summary Report

April 29, 1994

The findings and recommendations contained in this report were prepared by the interagency National Facilities Study Team and are endorsed by the Oversight Group members. They have not been approved by the participating agencies.

OVERSIGHT FORWARDING LETTER TO AGENCIES

April 29, 1994

To: Deputy Secretary, Department of Commerce
Deputy Secretary, Department of Defense
Deputy Secretary, Department of Energy
Deputy Secretary, Department of Transportation
Administrator, National Aeronautics and Space Administration

Enclosed, in accordance with the approved Terms of Reference, is the Summary Report of the National Facilities Study (NFS) team.

This report summarizes the results of the study plus the results from a study addendum which was undertaken to evaluate additional facility options.

In the report, the NFS team recommends development of two major new aeronautical wind tunnels with the primary objective of strengthening U.S. industry's capability to compete effectively in the rapidly expanding international market for commercial jet transports. It also includes specific recommendations regarding facilities required to meet the nation's space R&D/Operations needs, facilities consolidation across agency/department lines, and in some cases facility closure. In addition it identifies options which require further analysis but may provide additional opportunities for significantly improving both effectiveness and efficiency. These projects are recommended based on the merits cited, with recognition that final decisions require consideration of total national priorities.

The best measure of success of the study will be the extent to which it is effective in improving our efficiency in using limited resources and in encouraging improvements in our nation's competitiveness. This can only happen if, following your approval, the recommendations are examined by the organizations with line responsibility for the facilities and, where merit is found, are incorporated into revised operating plans.

The Oversight Group has periodically reviewed the National Facility study as it has progressed over the past year and offered guidance and support as necessary to make it a success.

We and the Task Team stand ready to answer questions and work with you and your staff at your request.

Chairman

Vice-Chairman

U.S. Aerospace Facilities

Space Research & Development

Aeronautics Research
& Development

Space Operations

Government and Industry
Contribute to Our Nation's Strength

NATIONAL FACILITIES STUDY
SUMMARY REPORT

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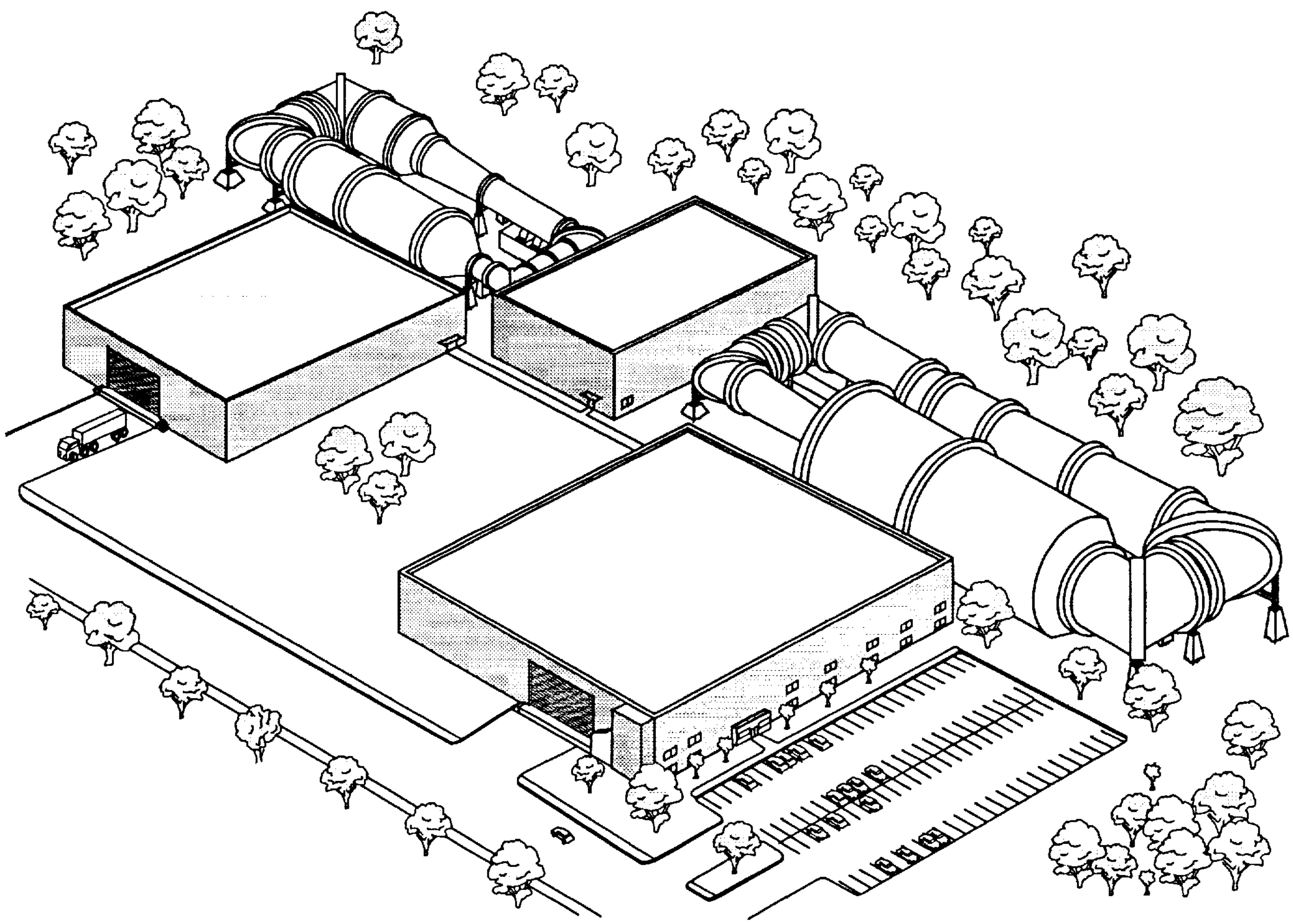
New Subsonic and Transonic Wind Tunnel Capability

Combining:

- High Performance
- High Productivity
- Low Operating Cost



VITAL TO U.S. AIR TRANSPORT INDUSTRY IN PRODUCING A CRITICAL COMPETITIVE EDGE

SUMMARY

This study provides a set of recommendations for improving the effectiveness of our Nation's aeronautics and space facilities. If the recommendations are implemented, they will provide world-class capability where it is vital to our country's needs and make us more efficient in meeting future needs.

AERONAUTICS FACILITIES

Two New Wind Tunnels Are Needed

Dominant among the new needs is the development of two wind tunnels primarily for future generations of commercial jet transports. These tunnels, one subsonic and the other transonic, would provide a combination of flight condition simulation and testing turnaround speed unmatched in this country or at any facilities abroad. Based on private industry's projections, they should be on-line around the year 2000 to provide the U.S. with the competitive edge needed for the next round of wide-body commercial transport competition. Site selection, when made, should be based both upon construction and operational cost considerations. We should move forward aggressively to put this vital new capability in place for our country.

Although aeronautics research and development (R&D) requirements were focussed primarily on development facilities for subsonic and transonic aircraft with primary emphasis on commercial needs, these tunnels would provide added value for military development. Requirements were also projected for hypersonic vehicles and propulsion needs throughout the flight regimes. Facility consolidation and closure options were addressed, including definitions of an action timetable.

SPACE R&D/OPERATIONS FACILITIES

Options for Consolidation or Improving Effectiveness were Evaluated

Excess facility capacity was identified and opportunities for improving effectiveness through consolidation and shared usage were identified. Facility shortcomings were also identified and recommendations are included for meeting these needs.

Seventy individual consolidation or closure recommendations have been collected, analyzed and validated. These include recommendations developed by the NFS Task Team and also endorsement of options or plans which are in some state of development by a specific agency, thus indicating a degree of receptivity already.

Cost savings and implementation costs have been determined for the recommended options. If they are implemented, the savings are estimated at $114M annually with a payback time for the investment of less than two years. Although the NFS has not included the cost and savings of the on-going USAF Range Standardization and Automation Program, the Range Operations Control Center, and the Centaur Processing Facility upgrade, their concepts and objectives are sound and we endorse these very large modernization programs.

Additional options have been collected but not yet sufficiently analyzed to allow a definitive recommendation. Reliance upon excess capacity at private industry sites has also not been fully explored. Recommendations are provided for continuing evaluation.

A Comprehensive Facility Inventory was Developed

In undertaking this study, aerospace facility inventories were found to be incomplete and outdated. The NFS Task Team developed a comprehensive computerized inventory of aerospace facilities at major NASA, DoD, DOE, NOAA, and industrial sites. The inventory data includes facility characteristics, performance features, an estimation of percent utilization, and contact points for additional information. The database contains over 2800 facilities and is still growing as additional government and industrial organizations provide inputs.

A Future Mission and Requirements Model was Developed

Another key need was to obtain a mission model for assessing future aerospace facility requirements.

A projection of future space mission requirements was developed for NFS analysis that embraces military, civilian government and commercial sectors to help determine what and how much of the inventory is expected to be needed. The mission model was constructed as a middle ground baseline with projections extended to 2023 because of the long lead time of certain facility related issues. Several excursions to the baseline were defined to test the sensitivity of facility recommendations to the baseline mission model.

The NFS Task Team urges that the recommendations be considered seriously by the responsible organizations and incorporated, or improved on, where possible. We stand ready to help with reviews and to support implementation planning where appropriate.

The momentum should not be lost; the data and tools developed during this study should be part of a continued effort to align our country's facilities to evolving national needs and to improve our efficiency.

INTRODUCTION

The United States aerospace industry has been subject to increasing challenge by international advances in aerospace technology that affect its ability to maintain its competitive position in the global marketplace. These advances are paced by modern, highly productive research, development, and operational facilities. A National Facilities Study (NFS) has been undertaken to formulate a coordinated national plan for aeronautical and space facilities that meet current and projected government and commercial needs.

A Terms of Reference (TOR) document was developed for the study (Appendix A). This formalized an Oversight Group, chaired by the NASA Associate Deputy Administrator, with the Department of Defense (DoD) Director, Test and Evaluation, Office of the Under Secretary of Defense (Acquisition and Technology), serving as Vice-Chairman, and with representation from other DoD and NASA offices, the Department of Commerce (DOC), Department of Energy (DOE), and the Department of Transportation (DoT).

The study plan considers current and future government and commercial needs as well as DoD and NASA mission requirements through the year 2023. It addresses shortfalls in existing capabilities, new facility requirements, upgrades, consolidations, and phase out of existing facilities.

STUDY APPROACH

The National Facilities Study Team was established in early 1993 with a director and four task groups as listed in Appendix B. The task groups were Aeronautics R&D, Space R&D, Space Operations, and Facilities Costing and Engineering. Each group was co-chaired by senior NASA and DoD leaders. Working groups supported the task groups in key specialty areas. The task groups had the responsibility for planning, directing, and providing recommendations in their particular areas of discipline for a plan which meets National aeronautics and space requirements and minimizes duplication of effort.

The situations in aeronautics R&D, and in space R&D/operations are quite different. It was recognized early in the study that there was an urgent need for new test facilities to support commercial air transport development, and the study emphasized that. In space there is some overcapacity, and the study emphasized this, although selected new capabilities are also recommended where the payoff is substantial.

Members of the National Facilities Study Task Team made on-site visits to key facilities. The task team surveyed the facilities and interacted with key personnel at the sites to obtain firsthand information. We are very appreciative of the time these people took from their schedules to help with this study.

Industry inputs and advice were solicited in various ways during the course of the study. In the case of the Aeronautics R&D Task Group with its special need to address commercial transport aircraft, experts from private industry participated as Special Government Employees, consistent with the Federal Advisory Committee Act. The Aerospace Industries Association was used to help establish contacts related to space facilities, and a special Industry Forum was organized at the Kennedy Space Center to gather specific company comments.

The National Research Council/Aeronautics and Space Engineering Board was requested to review the results of the NFS and offer an independent perspective and evaluation. They responded by establishing Aeronautics Facilities and Space Facilities subcommittees, each of which interacted with the NFS Task Groups, providing valuable commentary as the study progressed. They will issue reports in the June to July 1994 time period following their evaluation.

The study results, including the results of an addendum study instituted to evaluate additional facility options, are overviewed in this Summary Report. The following five separate volumes provide details and backup information:

Volume 1: Inventory
Volume 2: Aeronautics R&D
Volume 3: Mission & Requirements Model
Volume 4: Space Operations
Volume 5: Space R&D

INVENTORY DEVELOPMENT

It was clear early in the effort that an inventory of existing aerospace facilities had to be developed to perform the study. The scope had to include Aeronautics R&D, Space R&D and Space Operations facilities. Significant facilities in both government and private industry needed to be identified and categorized.

The Facilities/Engineering and Costing Task Group and the other Task Groups jointly developed a three-page format for the inventory. It includes a brief description of the facility, key operating parameters, capabilities, order of magnitude cost data, degree of utilization, and point of contact for additional information.

Data were solicited from all NASA centers, DOE, NOAA, and from the Army, Navy, Air Force, Advanced Research Projects Agency, and the Ballistic Missile Defense Organization. Industry participation was assisted by the Aerospace Industries Association and the American Institute of Aeronautics and Astronautics, leading to direct interaction with key companies. Each site (private industry or government) was provided a standardized data input package to report the characteristics of its facilities.

Guidelines were issued to limit the data inputs to the more significant key facilities. This still resulted in more facilities than could be evaluated in the time available, and approaches were developed by the task groups to focus on the areas most likely to pay off.

The information returned from the responding sites was merged into a single, comprehensive inventory, resident in a computer database for ease of access to the information. The database provided a number of analytical tools and capabilities to assist the task groups in performing their studies.

Data loading was, and still is, a dynamic process. Data were received at various times throughout the course of the study, and the database was appended as each new data set was received.

The NFS facility inventory is now the most comprehensive source of information concerning aeronautics and aerospace related facilities available. The inventory contains detailed information on 2,823 facilities from 78 sites. This represents over 8,000 pages of information. The following table summarizes the number of facilities contained in the database by agency and industry:

	# Sites	# Facilities
NASA	11	1,044
DoD	30	694
DOE	10	130
NOAA	3	51
Industry	24	904
TOTAL	78	2,823*

*Some data are proprietary and, therefore, not releaseable.

AERONAUTICS R&D FACILITIES

The United States commercial jet transport industry needs a major improvement in subsonic and transonic wind tunnel testing capability in order to compete effectively in the international market place. For many years, the U.S. has enjoyed significant economic benefit and military air superiority as a result of preeminence in aviation. In terms of economic impact, U.S. aviation industry sales exceeded $90 billion in 1991 and brought $28 billion to the U.S. in positive balance of trade, the largest of any industrial sector in the economy. Over 1 million high-quality jobs resulted. The outlook is even more impressive with future sales potential of $815 billion by 2010, and 65 percent of the sales being for foreign airlines, as shown in Figure 1.

The economic significance of aeronautics has not been lost on other countries, and in the past 20 years several countries have taken a very aggressive approach to establishing themselves as important competitors. Their successes are mirrored by the decline in the U.S. share of the global market. Since 1969, the U.S. share of the jet transport market has dropped by 30 percent and is predicted to continue to drop as shown in Figure 2 unless a vigorous program is undertaken to reverse this trend.

The Task Group on Aeronautics R&D Facilities examined the status and requirements for aeronautics facilities against the competitive need. Emphasis was placed on ground-based facilities for subsonic, supersonic and hypersonic aerodynamics, and propulsion. Subsonic and transonic wind tunnels were judged to be most critical and of highest priority due to their potential for impacting the market share. In this regard, ***the industry estimates that a 9-15 percent improvement in cruise and take off/landing performance is available and could be achieved with new high Reynolds number/high productivity wind tunnels. This is important because a 10 percent improvement in performance could result in an $80 billion increase in market share over the next 16 years and reductions in operator costs of $10 million for each year per new aircraft in commercial airline operation.***

FACILITY SURVEY/COMPARISON AND REQUIREMENTS

Subsonic/Transonic

An extensive inventory of worldwide wind tunnel facilities and their pertinent attributes has been accomplished in the study. Most of the facilities in the inventory set are used for academic, research, and exploratory purposes, not for the direct development of civil or military aircraft. The

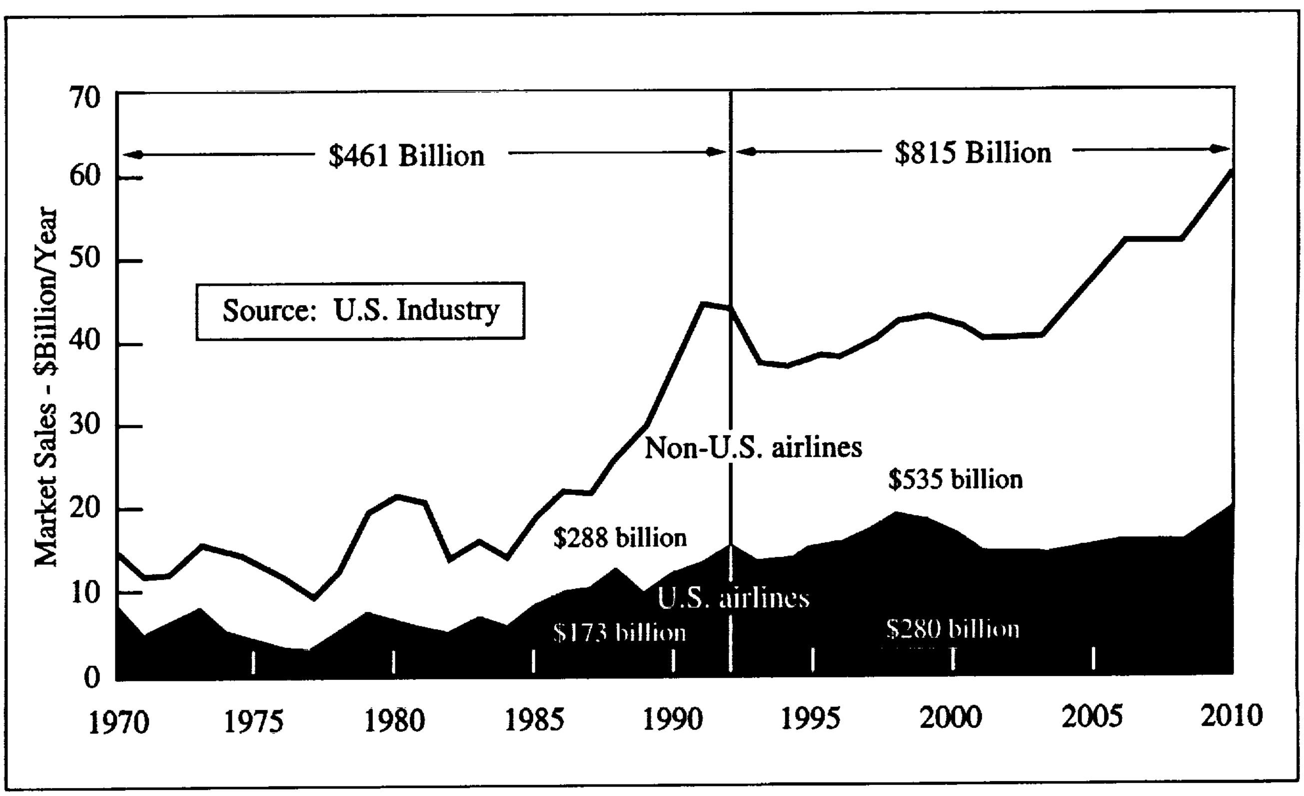


Figure 1. Market Growth Trends for New Aircraft

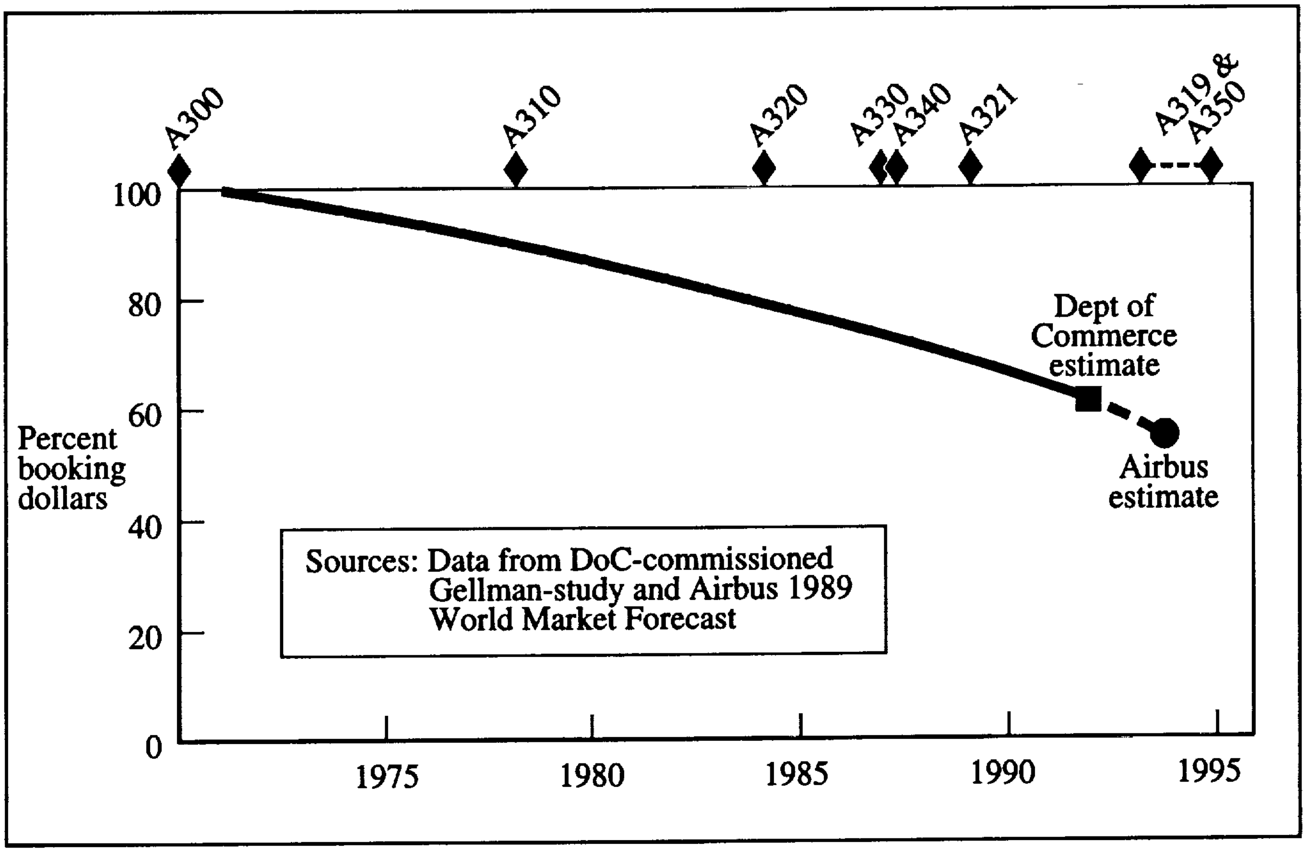


Figure 2. Trends in Commercial Aircraft Market Share for Major Companies

most meaningful subset, considered by a consensus of government and industry experts to be the core facilities for U.S. aircraft development, is presented in Figure 3. These core facilities are owned by the U.S. Government, U.S. industry, and foreign interests.

Three primary considerations were used in selecting the core facilities: capability (characterized by the aerodynamic parameter Reynolds number), productivity, and operating cost. The comparison metrics, maximum Reynolds number of the facility, productivity in terms of polars per occupancy hour (a polar is defined as 25 data points, each point being obtained at a single value of an independent variable), and test costs in terms of dollars per polar are included in the figure. In general, the data show that the higher the Reynolds number the lower the productivity and the higher the operating costs. The more modern European tunnels have achieved a better balance than the U.S. tunnels of capability, productivity, and cost, although the Ames 12-Foot Tunnel which is being rebuilt and will be reactivated in 1995, will have comparable metrics to the European subsonic tunnels. ***All of the world's subsonic tunnels, however, have serious limitations for the development of the complex high-lift systems to be implemented on future aircraft. It is the consensus of U.S. industry and government that substantial gains in Reynolds number, productivity, and cost metrics are needed to provide the U.S. with world-class capability.***

Facility	Reynolds no., millions	Polars per hr.	$ per Polar
Subsonic			
ARC 40 x 80	16.6	0.34	5965
ARC 80 x 120	10.8	0.34	5865
ARC 12-Ft. PWT	7.6	2.85	1300
LaRC 14 x 22-Ft.	3.2	0.6	1050
Lockheed 16 x 23-Ft.	3.9	3.5	225
Lockheed 8 x 12-Ft.	2.5	4.0	250
NAD 7 x 10-Ft.	2.0	2.5	200
DRA 5-Meter (Britain)	7.7	1.5	3000
ONERA F-1 (France)	7.5	1.7	3000
DNW (Netherlands)	3.6	4.0	1000
Transonic			
11-Ft.	10.3	2.15	2000
LaRC TDT	16.0	0.2	5000
LaRC NTF, Nitrogen	119.0	0.36	14300
LaRC NTF, Air	6.0	2.0	1537
AEDC 16T	9.6	4.5	1170
Boeing TWT	3.9	4.5	725
Calspan 8-Ft.	10.0	4.0	825
Rockwell 7-Ft.	7.0	2.0	1500
ETW (Europe)	50.0	1.5	5600

Figure 3. Summary of Reynolds Number, Productivity, and Operating Cost for the Core Development Wind Tunnels

Timing is also critical. To meet the needs most effectively, as shown in Figure 4, these tunnels should be on line by the year 2000 or as near thereafter as possible.

The Aeronautics Task Group, through a process of interaction with the nation's aeronautical experts, and analysis of the available data, arrived at target performance requirements for flow quality, productivity and cost: Reynolds number of 30 million, productivity at least 2 times greater than existing wind tunnels, and operating cost equal to or less than that of current major wind tunnels. Comparing these requirements with those of the "core" development facilities in Figure 3 leads to the conclusion that ***no U.S. facilities have the combination of capability, productivity, and cost metrics to provide the American aircraft industry with the technology that will permit U.S. firms to compete effectively.***

In order to maintain and improve the competitive position of the U.S. aircraft industry, it was a consensus of industry and government that improvements to existing national facilities will not suffice. The need exists for new wind tunnels with substantial increases in capability at subsonic and transonic speeds. They must provide Reynolds numbers above the threshold level at an operating cost equal to or less than the wind tunnels used today. The low operating costs can be achieved through high productivity levels.

New Wind Tunnels - The recommended approach results from substantial cost-benefit analysis between these options and the goals. The Low-Speed Wind Tunnel provides for efficient high Reynolds number testing (20 million on full span models at a Mach number of 0.3 as shown in Figure 5). The goal in Reynolds number of 30 million is achieved through the use of semi-span (large, half vehicle) models. It meets the productivity and cost metrics. The Transonic Wind Tunnel meets the goal of 30 million Reynolds number at a Mach number of 1 with full-span models as shown in Figure 6. It also meets the productivity and cost metrics.

The Aeronautics Task Group, through a process of interaction with the nation's aeronautical experts and analysis of the available data, arrived at a set of target performance requirements as follows: ability to test at full scale Reynolds number for some existing airplanes which will provide a baseline for extrapolation on larger airplanes (approximately 30 million, both subsonic and transonic); productivity of 2 to 2 1/2 times existing wind tunnels (5 polars per occupancy hour subsonic and 8 polars per occupancy hour transonic); operation cost equal to or less than current wind tunnels ($1000 per polar subsonic and $2000 per polar transonic); good flow quality; accessibility; and, acoustic treatment. Figure 7 shows the new wind tunnel complex which will meet these new commercial jet transport needs. A removable plenum section is used to facilitate the interchange of test

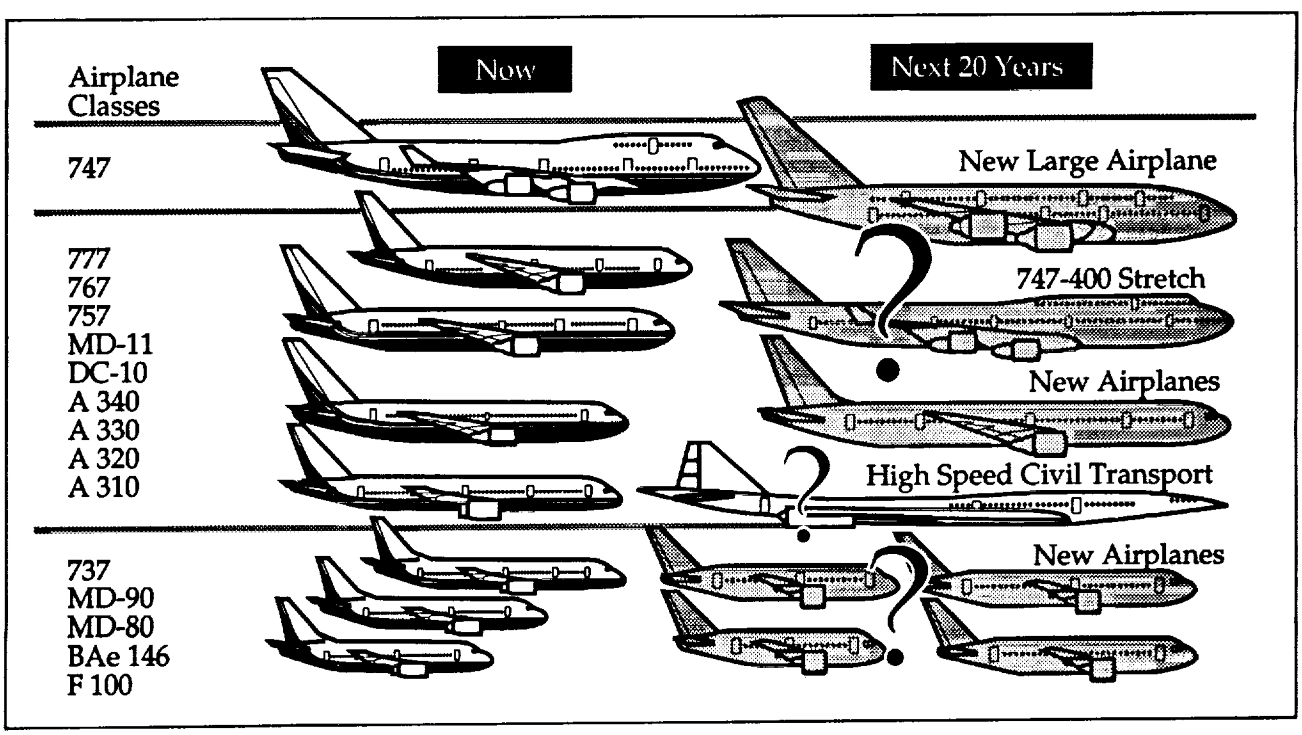


Figure 4. U.S. Commercial Aircraft Development Forecast

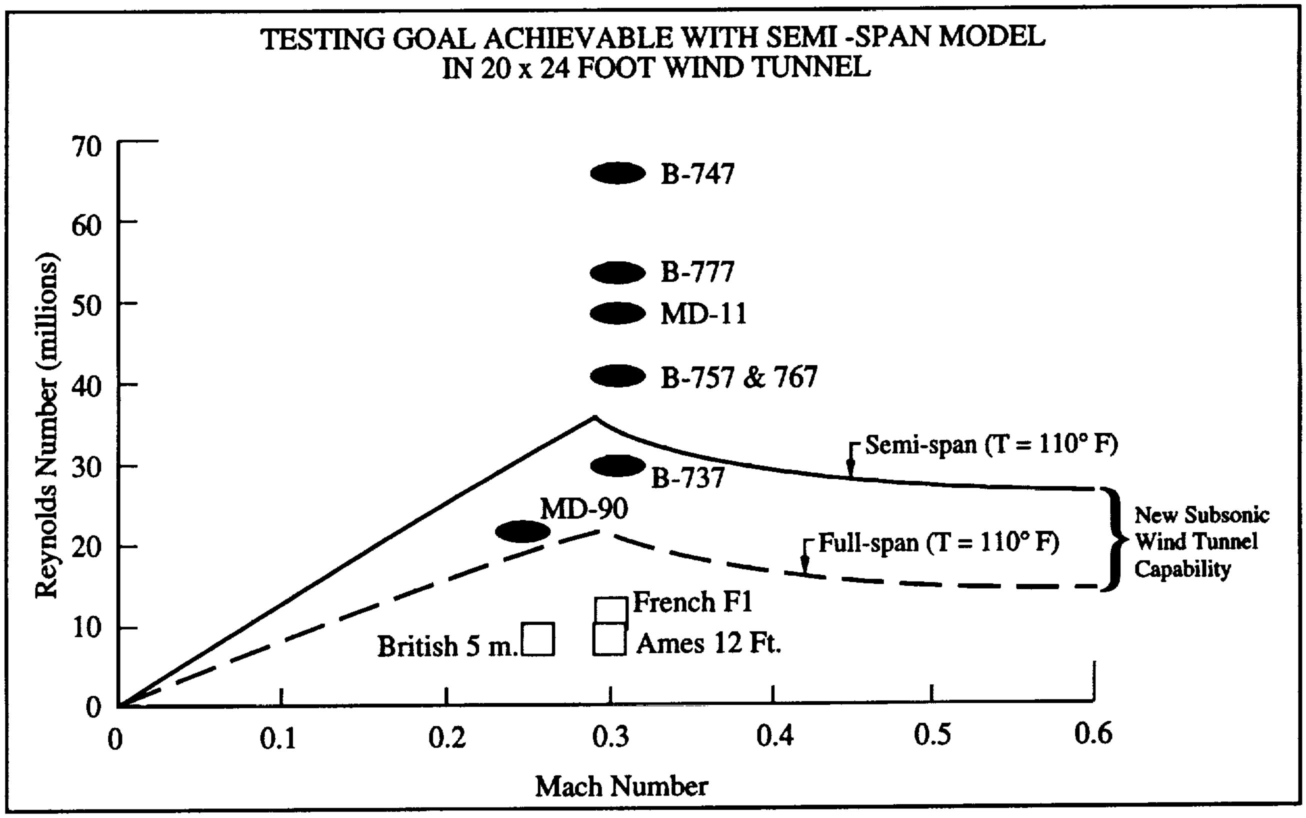


Figure 5. Comparison of Reynolds Number for Major Aircraft at 2nd Segment Climb with Low-Speed Wind Tunnel

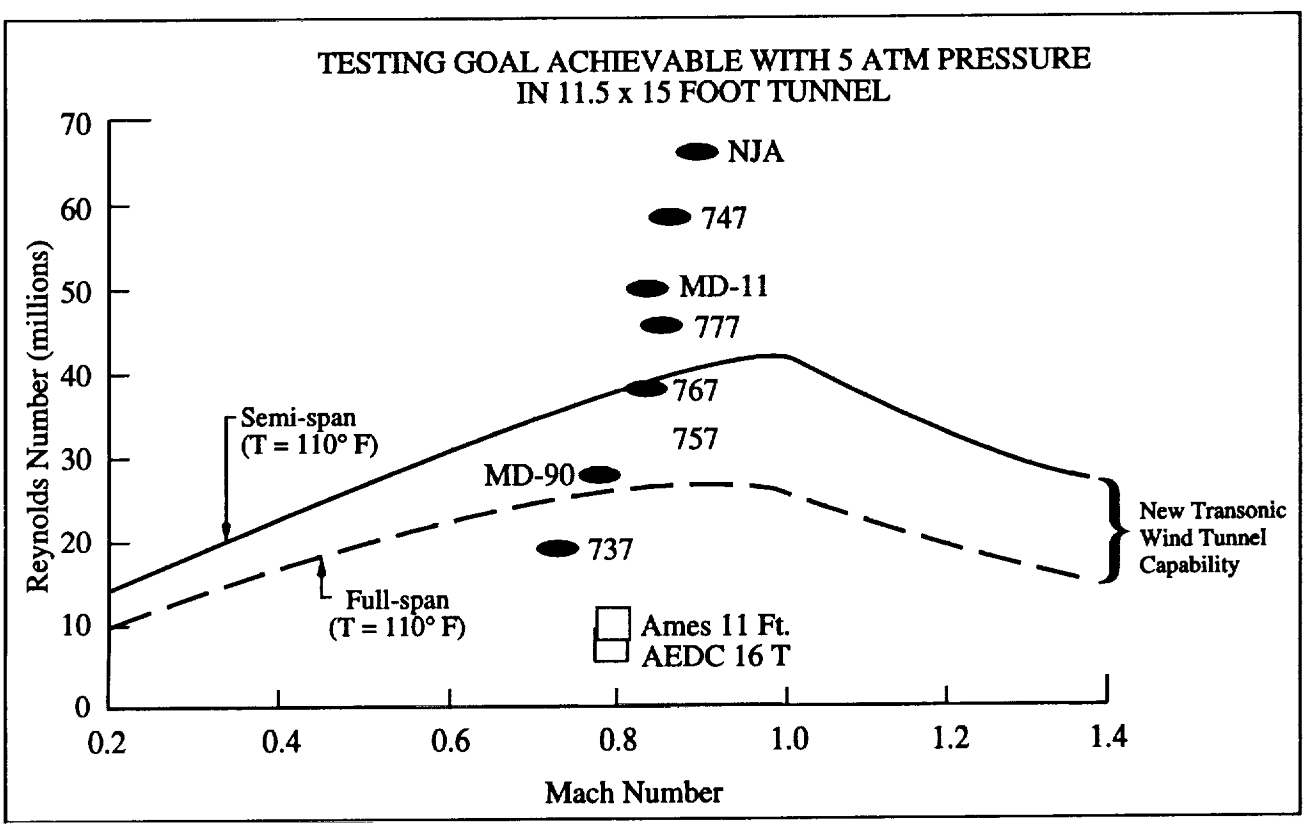


Figure 6. Comparison of Reynolds Number for Major Aircraft at Cruise with Transonic Wind Tunnel

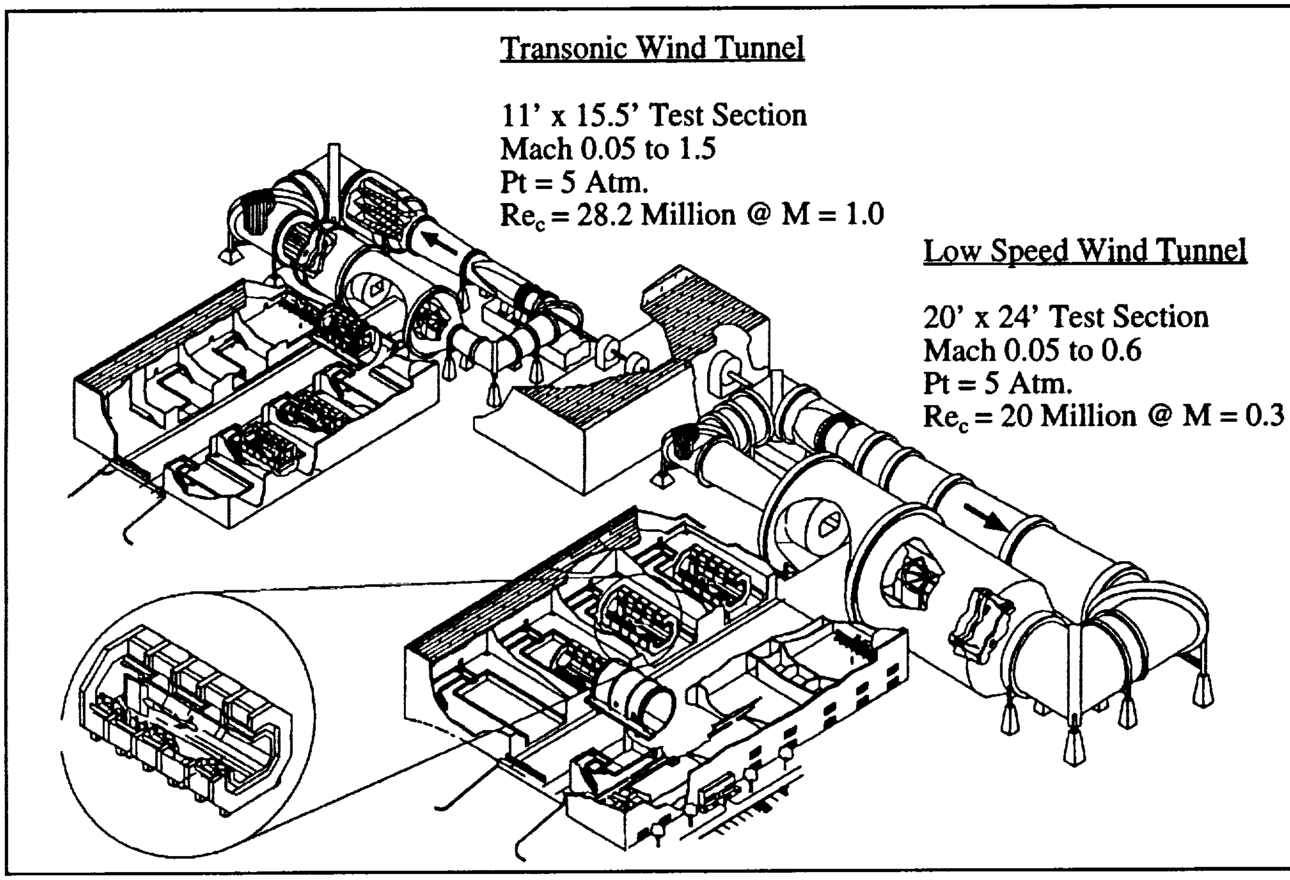


Figure 7. Proposed National Wind Tunnel Complex

sections and models to achieve the desired high productivity. Cost for planning and design, including the preliminary engineering report, government project management, special studies, final design, and construction were added to develop a ***total project budget estimate of $3.2 billion and a schedule of 10 years using normal government practices for acquisition, design, and construction. If nonstandard (i.e., commercial-like) acquisition and concurrent design and construction were feasible, the schedule could be reduced to 8 years and the cost reduced to $2.55 billion. These costs are believed to be conservative, and significant effort should be devoted in FY 1994 to both technical and contractual approaches to further reduce cost and schedule.***

It is important to note that these wind tunnels are not the most capable that could be produced. Indeed, reasonably detailed study of more than 10 options was accomplished with costs ranging from approximately $2 billion to almost $5 billion. Significant cost benefit analysis was done; this analysis process contributed significantly to the final definition of the metric requirements. ***The proposed new tunnels are a "better value" design solution; they represent an unmatched approach for combined capability, productivity, and cost.***

Supersonic Wind Tunnels

A new supersonic facility should not be constructed at this time; however, an investment to bring existing civil and defense facilities up to the productivity standards needed for commercial product development is recommended.

The capabilities of existing supersonic wind tunnels were examined, and it was determined that they fall short in terms of productivity and flow turbulence. These issues must be addressed by research prior to initiating efforts to acquire a new supersonic wind tunnel.

The primary demand for supersonic facilities has been from the Department of Defense and from its military aircraft manufacturers. Based on the input of those customers, today's facilities marginally satisfy the requirements for fighter aircraft and missile product development. In the future, the civil aircraft industry has plans for a supersonic airliner, currently referred to as the High-Speed Civil Transport (HSCT), which would cruise at Mach 2.0 to 2.4. The requirements for the HSCT can be met with the presently available supersonic facilities if proposed improvements

are made to the AEDC 16S Supersonic Wind Tunnel. Flight testing will be used to supplement the tunnel testing. There is a need to develop Supersonic Laminar Flow Control (SLFC) which is expected to significantly reduce HSCT operating costs. Until a new low-turbulence supersonic tunnel can be designed, ***research and development should be funded for 'quiet' flow supersonic wind tunnels,*** which will allow development of this key technology for future aircraft.

Propulsion Facilities

The Nation's propulsion facility infrastructure has been a major factor in U.S. competitiveness in the area of commercial aircraft engines. Continued advances in propulsion technology are critical to improving cruise economy and minimizing environmental impact in terms of noise and emissions, and in general, reducing aircraft acquisition and operating costs. In assessing future propulsion facility requirements, the focus was primarily on development facilities for future subsonic and supersonic commercial transports. ***The overall assessment was that, with a few exceptions, the U.S. industry and government laboratories have the largest and most capable propulsion facilities in the world.*** However, additional facilities may be required to ensure effective development of future propulsion systems in the areas of high mass flow for subsonic transports, inclement weather simulation, and full-scale engine tests for the High Speed Civil Transport. Upgrades to the Aeropropulsion System Test Facility (ASTF) for increased mass flow, supersonic free jet testing, engine/nozzle test capability, and increased capability in the Lewis Icing Research Tunnel may be required. These upgrades are on the order of $20 million each, except for the increase in mass flow which could be as high as $500 million. ***Because of the high cost and undetermined need, a two-year low level of effort study is recommended to define mass flow requirements for engines beyond the current generation (PW4000/GE90) before the mass flow upgrade is recommended.***

Hypersonic Facilities

Future flight systems are currently under study or development which will require ground test capabilities not in existence. These systems include orbital launch vehicles, air-breathing cruisers, interceptors (both ABM and theater air defense missiles), offensive missiles (cruise, maneuvering re-entry, and boost-glide), munitions, and space vehicles (rescue and planetary probes). Out of this array of systems, several are likely to be selected for full-scale development within the next decade, to be followed by various derivatives.

A two phased plan has been developed that addresses the hypersonic facility shortfalls. Phase 1 consists of a focused program of facility research and three important and needed facilities which can be built relatively soon with low risk and a modest investment. Phase II would be undertaken later to provide the needed systems certification facilities once the enabling facility technologies are in hand.

The focused program of research is clearly the most urgent need in hypersonics; it is required to select, develop, and demonstrate the most promising facility concepts. A $15 to $20 million/year research plan to be conducted by NASA, DoD, and industry is recommended.

CONSOLIDATION AND CLOSURE

Typical wind tunnel test hours for aircraft development have remained relatively constant over the last 20 years. The typical new aircraft, fighter or transport, requires from 20,000 to 25,000 test hours. A major derivative transport airplane such as the Boeing 737-300 or the McDonnell Douglas MD-11 requires 4,000 to 5,000 hours for development. From 1965 to present, the U.S. commercial aircraft industry has utilized an average of 15,000 test hours per year and projects this utilization to continue well into the next century. Recognizing a continuing demand for wind tunnel testing and the existence of other budget-related consolidation and closure activities, including the ongoing NASA infrastructure reduction and the DoD Project Reliance, the Aeronautics Task Group took an aggressive look at potential facility closures. A total of 44 major government-owned wind tunnels and propulsion facilities were considered. The facilities were grouped into four major categories: a) those considered to be unique and valuable national assets which were not considered further for closure because of their critical value and unquestioned need, b) those being worked as part of NASA infrastructure reduction, c) those to be worked for consolidation between agencies, and d) those impacted when the proposed new wind tunnels are available. The listing of facilities by category is shown in Figure 8.

In Category b), five major facilities are scheduled for closure between FY 1993 and 1995.

In Category c), the Ames/Army 7 x 10 Number 2 is scheduled to close in FY 1994. Consolidation of testing between the Langley 8 Foot High Temperature Structures Tunnel and the AEDC Aeropropulsion Test Unit (APTU) and between the Ames 100 mw arc tunnel and the AEDC H1 arc tunnel should be worked.

For Category d), it is difficult to predict the total impact of the proposed new wind tunnels on the utilization of existing wind tunnels 10 years in the future due to the broad range of wind tunnels currently utilized in aircraft development programs. However, there is consensus on several points: ***the U.S. industry will reduce or eliminate testing in Europe ($12 million per year); there will be a significant***

a. VITAL NATIONAL ASSETS
- Ames 40 x 80 x 120
- Langley Spin Tunnel
- Lewis IRT
- Langley NTF
- Langley TDT
- Ames 9 x 7 Supersonic
- Ames 8 x 7 Supersonic
- AEDC 16S
- AEDC 16T (Propulsion & Munitions)
- AEDC ASTF

b. BEING WORKED AS PART OF NASA INFRASTRUCTURE REDUCTIONS
- Langley 30 x 60
- Langley 7 x 10
- Lewis 9 x 15
- Langley 8 Ft. TPT
- Lewis 8 x 6
- Langley 4 x 4 (Unitary)
- Lewis 10 x 10 (Unitary)
- Ames 3.5 Ft.
- Langley 60 in. Helium Tunnel
- Langley M = 18 Nitrogen Tunnel
- Lewis PSL

c. CONSOLIDATION BETWEEN AGENCIES
- Ames 7 x 10 (#1)
- Ames/Army 7 x 10 (#2)
- AEDC 4T
- AEDC Tunnel A
- ARC 100 MW ARC
- Langley 8 Ft. HTT
- Lewis HTF
- AEDC APTU
- AEDC H1 ARC
- AEDC Tunnels B&C
- NSWC Tunnel 8&8A
- Sandia Hypersonic Wind Tunnel
- AEDC T-1, T-2, T-4, T-6
- AEDC J-1, J-2

d. IMPACT OF NEW TUNNELS
- Ames 12 Ft. PWT
- Langley 14 x 22
- Ames 11 Ft. (Unitary)
- Langley 16 Ft. TT
- AEDC 16T (Aerodynamics)
- U.S. Corporate
  - Boeing TWT
  - Others TBD
- Use of Foreign Wind Tunnels

Figure 8. Listing of Facilities by Category

reduction in use of industry-owned tunnels with closing of some, i.e., Boeing Transonic Wind Tunnel (approx. $20 million per year); and major government development oriented wind tunnels such as the Ames 12-Ft. and 11-Ft. Tunnels and the AEDC 16T will be phased down/out (approximately $20 million per year). The status of facility consolidation is summarized in Figure 9.

NATIONAL FACILITY PLAN

The recommended facility actions are summarized in Figure 10.

• NASA Infrastructure Reduction		
• Langley 7 x 10	Closed	FY 93
• Ames 3.5 Ft.	Close	FY 94
• Langley 8 Ft. TPT	Close	FY 95
• Langley 30 x 60	Close	FY 95
• Lewis HTF	Close	FY 95
• Consolidation Between Agencies		
• Ames/Army 7 x 10 #2	Close	FY 94
• Langley 8 Ft. HTT/AEDC APTU (being worked)		
• Ames 100 mw arc/AEDC H1 arc (being worked)		
• Impact of New Tunnels		
• Ames 12 Ft. PWT • Ames 11 Ft.	Reduce to one shift at activation of new wind tunnels. Place on operational standby when new wind tunnels achieve full operational status.	
• Langley 14 x 22 • Langley 16 Ft. TT	Review at activation — action dependent on ability of new wind tunnels to accommodate functions.	
• AEDC 16T	Reduce to propulsion and munitions testing only.	

Figure 9. Status of Facility Consolidation

Subsonic/Transonic

- Construct 20 x 24 Ft. High Rn Low-Speed Wind Tunnel . . . . ~\$1500M
- Construct new 11.5 x 15 Ft. High Rn Transonic Wind Tunnel. . . . . ~\$1500M

Supersonic

- Upgrade productivity/reliability of AEDC 16S 42M
- Conduct R&D for M = 2.0 to 2.4 Quiet Tunnel — 4 M/yr. for 3 yrs.. . . . . . . .12M

Propulsion

- Conduct study to determine mass flow requirements for next generation engines . .1M
- ASTF upgrade
  - — Potential upgrade to ASTF mass flow capability (based on study). . . . . . TBD
  - — Supersonic freejet capability in ASTF. 20M
  - — Mods for engine/nozzle tests (ASTF) 15M
- Upgrade Lewis Icing Research Tunnel 20M

Hypersonics

- Conduct R&D on facility concepts for T&E — 20 M/yr. for 10 yrs. 200M
- Construct Phase I Aerothermodynamic Facilities 220M
- Construct Phase II T&E Facilities (based on R&D program). . . . . TBD

Figure 10. Recommended Facility Actions

Implementation of these actions on the schedule shown in Figure 11 will result in the right facilities required for the U.S. aeronautics industry to compete effectively in the world market. The payoff will be in U.S. jobs and the U.S. economy; it will be realized in helping to maintain and increase the U.S. share of an \$815 billion market over the next 16 years.

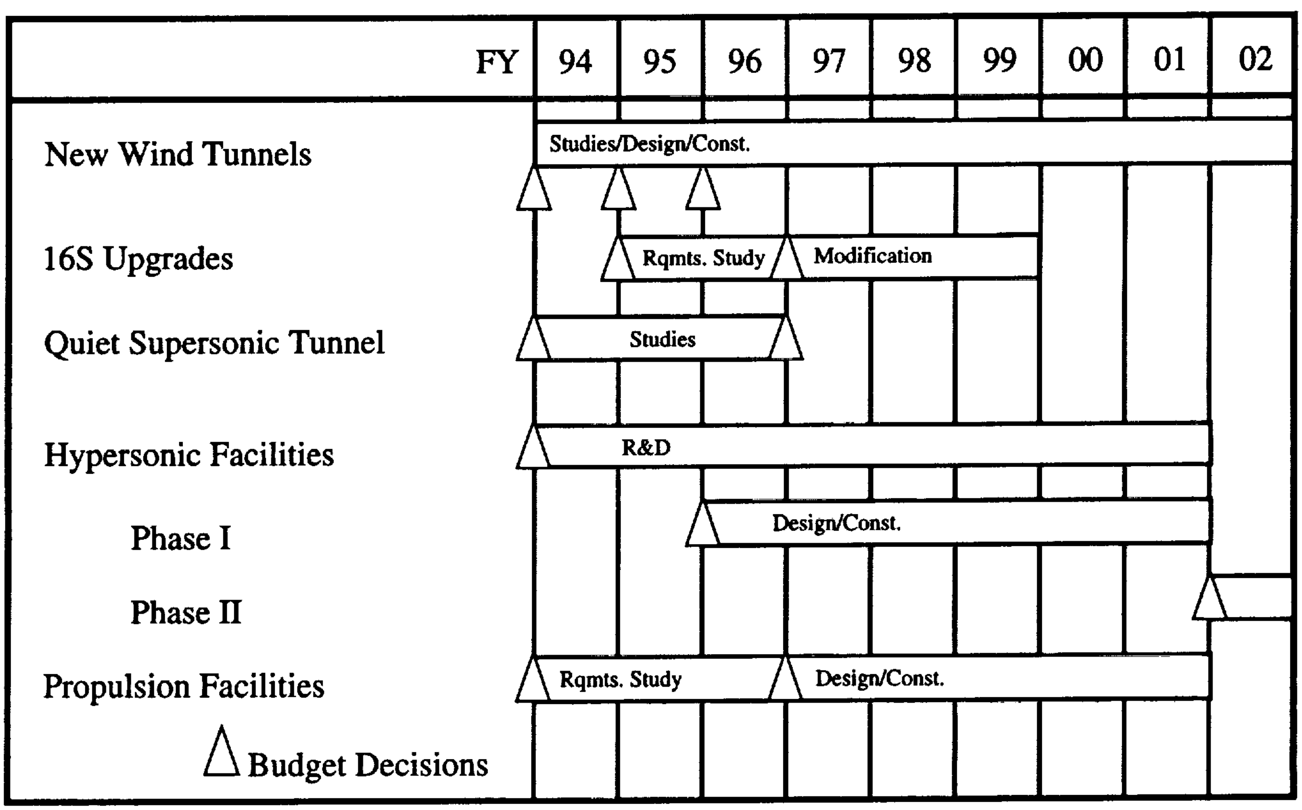


Figure 11. Proposed Implementation Plan

SPACE MISSION AND REQUIREMENTS MODELS (BASELINE AND EXCURSIONS)

Space facilities decisions require an assessment of current and future needs. Therefore, the two task groups dealing with space developed a consistent model of future space mission programs, including both operations and R&D. The resulting model is a middle-ground baseline constructed for NFS analytical purposes with excursions to cover potential space program strategies. (As agency and Administration decisions impacting the mission model were made, the model was updated to reflect those decisions.) The model includes three major sectors: DoD, civilian government (e.g., NASA, National Oceanic and Atmospheric Administration (NOAA), etc.), and commercial space (e.g., the telecommunications satellite industry). The model spans the next 30 years because of the long lead times associated with facilities development and usage.

The DoD members of the Space Operations and R&D Task Groups developed the military elements of the requirements model. NASA members of the task groups integrated the civilian government portion. Commercial space requirements were provided by DOT's Office of Commercial Space Transportation using inputs from the Commercial Space Transportation Advisory Committee. For each sector, a baseline forecast of future missions, supporting programs (e.g., R&D), and launch requirements was developed and integrated for the period 1993-2023. The goal of the baseline was to provide a common, conservative basis for facilities requirements, analysis, and recommendations. In addition to this baseline, a set of 'excursions' was also defined to test the sensitivity of facility recommendations to the mission model and to take into account future program directions considered likely by the task group.

BASELINE MODEL

Overall, the baseline model forecasts continuing operations of many current existing systems with very selective new systems. (Figure 1 in Appendix C provides a summary view of the baseline space launch mission requirements model including launch vehicle class and user for the period 1993-2023.) Selected, significant baseline model features of the three basic sectors are as follows:

Commercial. The baseline model for civilian commercial space activities includes continuing manufacture, launch, and operations of existing systems (with periodic block upgrades), augmented by selected major systems developments. Areas include the following:

- Launch Systems. The model forecasts continuing operation of existing commercial expendable launch vehicle (ELV) fleets through 2023, and development of a new family of small payload low-cost ELVs after 1998.

- Telecommunications. The model forecasts continuing operations of radio frequency geostationary telecommunications satellite systems, with block upgrades to 2023; and after 1995-1998, initiation of 1-2 low Earth orbit telecommunications constellations, with block upgrades through 2023.

- Earth Observing/Remote Sensing. The baseline includes modest commercial Earth remote sensing satellite operations following 2003.

- Materials Processing In Space. The forecast is for modest commercial materials processing operations following 2003.

Civilian Government. The baseline model for civilian government space activities forecasts continuing operations of existing systems as well as several major new systems developments after 2000-2005. In addition to ongoing mission-supporting manufacturing (e.g., in industry), launch (e.g., Kennedy Space Center), and operations (such as the Deep Space Network), baseline areas include the following:

- Mission to Planet Earth/Earth Observing. The forecast calls for completion of the initial Earth Observing System series, development & operations of a second series through 2023 with small to medium size platforms, and NOAA weather satellite systems (and upgrades).

- Space Science/Mission From Planet Earth. The model includes completion of the Great Observatories, followed by small & moderate-class Earth orbit science missions, and a strategic changeover to small to moderate-class, deep space probes after the launch of the flagship-class Cassini Mission to Saturn.

- Space Exploration and Development. The baseline includes Space Shuttle operations (with upgrades) and the current expendable launch vehicles (with upgrades) through the 2023 timeframe; development and launch of international redesigned space station with European, Japanese, Canadian, and Russian elements and U.S. launch with continuing operations through the 2023 timeframe; and phased transition of the Deep Space Network (DSN) to Ka-Band communications in 2003-2008.

- Space Technology. Programs include mission-supporting R&D, such as selected NASA technology flight experiments (on Shuttle, Station, etc.), and NASA R&D programs (including power, propulsion, small spacecraft, etc.).

Department of Defense. The baseline requirements model for DoD space activities includes continued operation and block upgrades of major DoD space systems and some new system developments in the post-2000 timeframe, as well as R&D to prepare for future systems deployment decisions. Areas include the following:

- Communication and Navigation. The forecast includes Military Satellite Communications systems operations and block upgrades and continuing operations of current NAVSTAR Global Positioning System.

- Surveillance/Earth & Weather Observing. The baseline projects development and deployment of Early Warning Systems (including DSP), launch and operation of GEOSat Follow-On (GFO) mission, and deployment and continuing operations of Defense Meteorological Satellite Program (DMSP) systems and upgrades.

- Missile Offense and Launch Systems. The model projects continuing Intercontinental Ballistic Missile Systems operations and upgrades and operations and upgrades of current launch systems including current vehicles and ground infrastructure.

- Technology Development and Flight Experiment Programs. The forecast includes supporting programs, such as R&D areas and/or programs and technology flight programs.

- Classified Mission and Programs Appropriate for the Baseline.

Launch Operations. Each of the three sectors described above require significant space launch operations, with the predominant utilization of U.S. west coast facilities by the DoD and mixed use of east coast facilities. (Figures 1 and 2 in Appendix C provide the forecast of utilization by sector for each range.)

EXCURSIONS

In addition to the baseline model, a series of excursions was developed for both space task groups.

For the Space Operations Task Group, a single excursion was developed examining the impact of a future decision to develop a new Highly Reusable Vehicle (HRV) for access to space (such as a Single-Stage-to-Orbit (SSTO) vehicle).

For the Space R&D Task Group, three broad options were considered, including the development of several significant new systems in the post-2000 timeframe in all three sectors, paralleled by increasing support to U.S. industry by related (predominantly civilian) government space R&D programs. For example, in commercial space a new cargo-carrying vehicle was projected to meet growth in low Earth orbit (LEO) communications systems, in commercial Earth observing and/or remote sensing, and in materials processing in space (beginning in the post-2003 timeframe). Similarly, in the civilian government sector, the excursions forecast new systems for Mission to Planet Earth (e.g., geostationary platforms following completion of the initial EOS), for space science (such as Next Generation Space Observatories in post-2008), for human exploration and space development (such as replacement of the Shuttle by a Highly Reusable Vehicle and deep-space human exploration), as well as growth in space technology efforts in ground-based R&D and technology flight experiments. Finally, for DoD, excursion projections included launch and operations of GPS II for improved navigation, new multi-spectral surveillance systems, a Next Generation Launch System, potential deployment of missile/theater defense systems, and classified missions and programs appropriate for the excursion.

SPACE OPERATIONS FACILITIES

Three functional facility areas were defined to assess space operations facilities: Manufacturing; Mission Operations and Training; and Payload Processing, Launch, and Recovery. Data were collected on facilities including commercial and government-owned manufacturing facilities, NASA, Navy, NOAA, and Air Force space operations facilities and a limited number of Army facilities. Although the facility inventory was not completely developed during this initial phase of the study, it is felt that the major facilities involved in space operations activities have been included.

Significant findings and conclusions which emerged during the evaluation are as follows:

- The baseline mission model projection for the next 30 years can be met with existing facilities with only small additions (e.g., Neutral Buoyancy Laboratory for Space Station). Improvements must be made to strengthen and enhance efficiency of the facility infrastructure, (e.g., Air Force Range Standardization and Automation Program).

- Facilities required to support implementation of new launch vehicles such as a highly reusable launch system (e.g., single-stage-to-orbit (SSTO)) are highly dependent on the specific configuration being considered and the degree with which program objectives are directed toward reducing launch costs. The requirements of most of the concepts, however, can be met by modification of existing facilities.

- Budget reductions and program cancellations have produced an underutilization of the capacity of many space operation facilities. This has led to excessive operations and maintenance costs and inefficient use of personnel. At the same time, a significant number of the government's key facilities suffer from underfunding for maintenance, restoration, and modernization.

- Substantial cost savings can best be realized when consolidation of activities results in reduced personnel requirements through increased efficiency and elimination of duplicative effort. Closure and consolidation of facilities, thus avoiding annual operations and maintenance costs, provide only a modest savings.

- Redefined/realigned functions and responsibilities within and between the agencies, which decrease overlap and clarify respective responsibilities would allow more significant reductions/consolidation in facilities, people, and programs. This is most pronounced in command and control, training, tracking, and, in a more limited way, launch support facilities.

- Facilities are constructed and operated primarily in support of program requirements. There are no coordinated processes at the agency level or between agencies, for providing continued institutional support of program facilities that may be needed in the future when the sponsoring program has been terminated or completed.

- The task group found evidence of facility deterioration and obsolescence which significantly constrains efficient and effective facility performance. This conclusion has been previously noted by various studies within NASA and DoD. In general, NASA and DoD spend approximately two percent of current replacement value for facility maintenance compared to a recommended three-four percent. Facilities should be consolidated and closed where practical, and facility maintenance budgets should be better focused to reverse the current trend of deterioration and obsolescence of remaining facilities.

- At operational locations where multiple agencies co-exist, the study team found many noteworthy instances of agency-to-agency cooperation and sharing which can serve as a model for the future. For example, an Air Force/NASA liaison team operates at Cape Canaveral Air Force Station (CCAFS) and Kennedy Space Center (KSC) to coordinate range and launch scheduling, facilities usage and sharing, and other activities. NASA representatives attend Air Force range scheduling and operations review meetings, and the KSC Center Director and the Air Force's 45th Space Wing Commander conduct a joint quarterly management meeting. There are many other examples. Many functions, such as medical support and propellant services, are administered by one agency but include support to the other agency as appropriate. NASA and DoD should formally adopt this approach within our agencies as the preferred way of doing business.

The facility database used in the analysis is described in Volume I of this report. The facilities selected for analysis were based on database information, the experience and knowledge of team members and selected site visits by each of the working groups. The facilities evaluated in this initial study effort are summarized in Figure 12.

	INVENTORY				SELECTED FOR ANALYSIS				COMMENTS
	NASA	DoD	OTHER	TOTAL	NASA	DoD	OTHER	TOTAL	
PAYLOAD PROCESSING, LAUNCH, & RECOVERY	357	345	0	702	352	217	0	569	Several facilities support multiple agencies. Category selected based upon most dominant sponsor.
MISSION OPERATIONS & TRAINING	91	85	16	192	67	31	5	103	
MANUFACTURING	6	12	0	18	5	8	0	13	

Figure 12. Space Operations Facilities Evaluated

The facility recommendations were then categorized as follows:

Category 1A: Recommended changes to the status quo or advocated ongoing changes that are consistent with national facilities study objectives.

Category 1B: Recommended no change (facility required to support mission model).

Category 2: Further study is needed and is merited based on preliminary analysis.

Category 3: No recommendations made at this time due to a lack of data, insufficient time to assess, and in some instances an initial assessment of no significant cost savings to be realized.

The 40 Category 1A facility recommendations, implementation cost to effect the consolidation, upgrade and closure, and the resultant cost savings are summarized in Figure 13. These 1A recommendations affect 144 Payload Processing, Launch and Recovery facilities, 12 Mission Operations and Training facilities and 6 Manufacturing complexes. Special mention is made of three DoD projects that were underway prior to this study and will provide significant facility improvements and reduce operating costs for all users at the Cape Canaveral and Vandenberg launch and range facilities. The NFS strongly endorses these projects, but does not include their costs and savings in the database as they are not initiatives of the study. Projects include (1) Range Standardization and Automation (RSA) which consolidates and automates Eastern/Western range operations and saves $245M between 1996-2001; (2) continued activation of the Range Operations Control Center (ROCC) which replaces 40 year old equipment for mission management and range safety; and (3) construction of the Centaur Processing Facility (CPF) which will improve operational efficiency for the approximately 30-35 Titan/Centaur launches projected between now and 2023.

Other key recommendations and their projected annual or one-time savings include the following:

- Consolidate Defense Meteorological Satellite Program (DMSP) dedicated facilities from Fairchild AFB, WA and Offutt AFB, NE to Falcon AFB, CO. This eliminates redundant facilities and eliminates the need for additional communication circuits. ($2.5M annual)

	NUMBER RECOMMEND.'S	TOTAL IMPLEM. COST - $M	ONE TIME SAVINGS/COST AVOIDANCE - $M	TOTAL ANNUAL SAVINGS/COST AVOIDANCE - $M
PAYLOAD PROCESSING, LAUNCH, & RECOVERY	29	21	26	34
MISSION OPERATIONS & TRAINING	5	56	21	17
MANUFACTURING	6	2	2	9
TOTAL	40	79	49	60

Figure 13. Consolidation Recommendations/Endorsements (Category 1A)

- Move Air Force space operations training facilities from leased spaces in Colorado Springs to Falcon AFB. This provides better crew access, better squadron integrity, reduces Automatic Data Processing Equipment costs and eliminates lease costs. ($2.0 annual)

- Construct a Neutral Buoyancy facility at Johnson Space Center (JSC) to support the Space Station program and close existing Neutral Buoyancy facilities at JSC and Marshall Space Flight Center (MSFC). This will consolidate crew training, reduce travel, provide higher fidelity training, reduce mock-up and suit costs and allow concurrent set-up and training. ($5.0M annual)

- Close NASA Slidell Computer Complex and relocate External Tank (ET) operations to Marshall Space Flight Center. This consolidates operations under one contract, lowers overhead burdens and eliminates operations and maintenance costs for a large facility. ($9.0M annual)

- Divest underutilized Air Force facilities at General Dynamics in San Diego, CA (Plant 19), Aerojet in Sacramento, CA (Plant 70) Thiokol in Brigham City, UT (Plant 78) and AF Plant PJKS to reduce cost of ownership and facilities management responsibilities. ($2.2M one-time)

- Cancel requirement for construction of a new Space Shuttle Main Engine (SSME) facility at KSC and consider expansion into existing facility. Satisfies requirement for additional space but utilizes available facility at KSC. ($5.0M one-time)

- Transfer antennas at Fort Irwin, CA from the Army to NASA, thus avoiding major antenna procurement. Provides NASA additional deep space capability earlier than predicted, at a lower cost. ($16.0M one-time)

- Consolidate Spacelab data processing from Goddard Space Flight Center (GSFC) to the Payload Operations Control Center (POCC) at MSFC to improve efficiencies. ($5.0 annual)

Category 2 facility recommendations are summarized in Figure 14. These include a number of recommendations which require review by several agencies to properly assess feasibility and the potential for cost savings and efficiencies. It also includes other recommendations for which an assessment of program impact is required to ensure that program schedules, cost and technical content are not compromised.

	NUMBER OF RECOMMENDATIONS
PAYLOAD PROCESSING, LAUNCH, & RECOVERY	23
MISSION OPERATIONS & TRAINING	11
MANUFACTURING	2
TOTAL	36

Figure 14. Category 2 Recommendations.

The most significant recommendations for continued evaluation (Category 2) are as follows:

- Consider establishing a multi-agency task force to study network optimization and operational consolidation. The historic development of independent satellite command and control systems has resulted in reduced interoperability between Government-owned systems and less than optimal utilization of resources and facilities. A unified approach to operations, infrastructure, and procedures could improve use of existing capabilities, increase efficiency, and reduce overall command and control infrastructure.

- Study the consolidation of multiple satellite operations centers into a smaller number of modern facilities. Consolidation would take advantage of latest technology, saving manpower and unique hardware implementation costs.

- Evaluate consolidating Onizuka AFB satellite operations with those at Falcon AFB, two GPS squadrons at Falcon AFB into one and multiple DSP ground stations units into one. Provides efficiency in personnel, logistics and floorspace.

- Study the consolidation of NASA activity at the NASA Industrial Plant at Rockwell Downy and AF Plant 42 at Palmdale, CA. Upon completion of orbiter major modifications, personnel efficiencies may be realized by reassessing continued hardware manufacturing and assembly requirements.

- Evaluate consolidation of range functions at Bermuda, Wallops Island, Merritt Island and Ponce de Leon through the RSA program, replacing these facilities with simpler, modern, fixed or mobile remote unmanned installations.

- Consider transferring Explosive Safe Area 60A, High Energy Radiology Facility and Hangars AO and AM at Cape Canaveral AFS from NASA back

to the Air Force. NASA's requirement for these facilities is expiring and the Air Force should seek new users, including the commercial sector.

- Consider using underutilized Titan facilities at Cape Canaveral for support of Delta assembly and processing.

Key Category 1 recommendations are summarized in Figure 15, which also provides a recommended time table for implementing the recommended activity or supporting studies.

RECOMMENDATION	FEB 94	MAR 94	APR 94	MAY 94	LATE 94	FY95	FY96	FY97	FY98	POST FY98
Consolidation of Dedicated DMSP Facilities							△ Phase 1			△ Phase 2
Move AF Space Operations Training to Falcon AFB		△ Phase 1			△ Phase 2					
Construct Neutral Buoyancy Facility, Close WETF, NBS						△		△		
Close Slidell Computer Complex		△				△				
Support Divestiture of AF Plant Facilities				△ AF Plant 19		△ AF Plant 70 △ AF Plant 78		△ AF Plant PJKS		
Yellow Creek Explore Alternate uses of Fac.	△		△ RSRM Nozzle Facility			△ 1Q				
Cancel Construction of SSME Shop, Expand in an Existing Facility	△ Cancel Construction				△ Expand in Existing Facility		△			
Transfer Fort Irwin Antennas from Army to NASA			△ MOA			△ Implementation				
Range Standardization and Automation	←				△ ER ROCC IOC		△ GPS Tracking IOC	Additional Upgrades thru 2003	△ Antigua CIF IOC Ascension CIF IOC △	→
Support Commercial Space Ventures			SLC-6 Payload Preparation Rm	△	△ Transfer VAFB Scout Facilities △ Assign SLC-6 Admin Facilities for Commercial Use △ Assign SLC-6 Launch Pad Area for Commercial Use △ Commercial Spaceports △ Modify CX46 for Small Commercial Boosters					△ Commercial Use of ABRES A&B, 576
Mothball/Abandon Launch Pads					△ Mothball Pad 3A Scout Launcher (WFF) △ Pad 4 (WFF)					
Upgrade Poker Flat Research Range					△ Construct Rocket Assembly Building "C" △ Upgrade Launch Area3 △ Construct Telemetry Facility	△ Construct New Science Operations Center				
Consolidate Spacehab Data Processing Facility	△ Study		△ GSFC/MSFC MOA			△ Implementation				
Cancel Proposed New EOS Processing Facilities		△ Cancel Construction								
Surplus/Find Use for Hypergolic Storage Facility at CCAFS			△ Identify Potential Uses		△ Match Use(s) with Requirements or Surplus					

Figure 15. Space Operations Schedule (Category 1 Recommendations)

Figure 16 shows an approximate schedule for some of the major Category 2 actions if further analysis validates the recommendations. The Space Operations Task Group's recommendations for all Category 1 and 2 facilities and a complete listing of Category 3 facilities are included in Volume IV of this report.

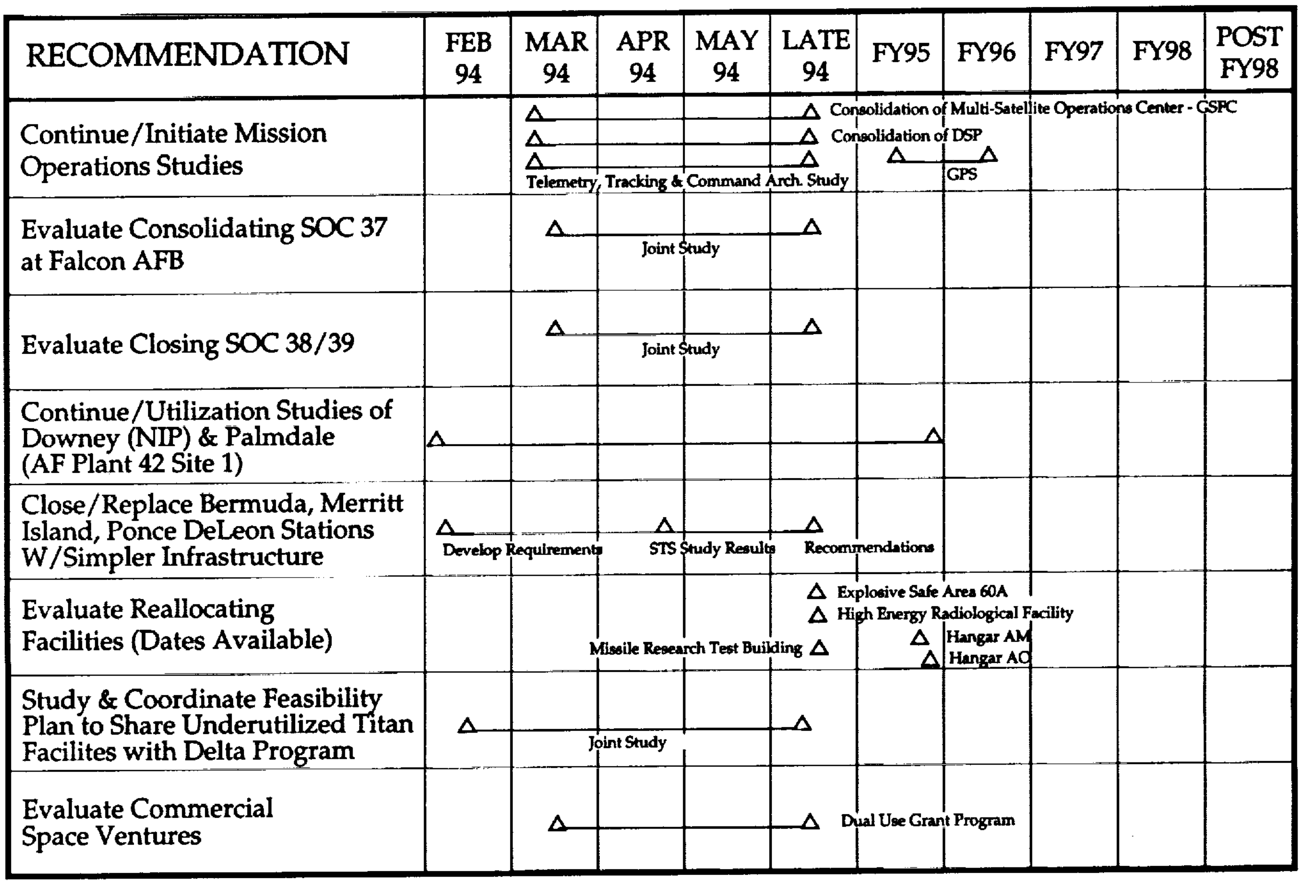


Figure 16. Space Operations Schedule (Category 2 Potential Recommendations)

SPACE R&D FACILITIES

This Task Group evaluated space research and development in four functional groups: Human and Machine Operations; Information and Communications; Propulsion and Power; and Materials, Structures and Flight Dynamics.

The working groups identified and collected data on over 650 facilities including NASA, Air Force, and a limited number of Army, Navy, and industry facilities. The working groups augmented the inventory through personal knowledge and site visits. It is believed that this activity captured the major facilities involved in space research and development.

Several significant findings and general conclusions resulted and are listed below:

- The baseline mission model for the next 30 years can be met with existing facilities. However, there is a need to make a national commitment to upgrade and maintain key facilities in a world-class condition. A systematic and properly funded maintenance program and decision making plan to incorporate enhancements usually must lead the detailed commitment of the program requiring the facilities.

- One new facility for composite structures and materials would provide an important competitive edge.

- The unique facility needs of the mission model excursions (e.g., single-stage-to-orbit technologies) can be met mostly by upgrades and/or modifications to existing facilities. An excursion such as human return to the moon for an extended stay or a human mission to Mars would, however, require new facilities. Most costly would be those required for nuclear propulsion development.

- There is an over-capacity in some areas of government-owned space R&D facilities. Also, there is over-capacity in some areas of industry owned Space R&D Facilities. Determining the proper balance between the government and industry will have a significant impact on future facility decisions.

- Significant savings associated with facility closure and/or consolidations can only result by reducing personnel associated with those facilities. Some improvements in efficiency can be made with the current understanding of roles and responsibilities. A conscious examination of the roles and missions may yield far more return. From a facility standpoint, the areas for greatest payoff are

  - rocket propulsion
  - spacecraft integration
  - large vacuum chambers

- At several locations where multiple agencies exist, the Task Group found excellent examples of agency-to-agency and intra-agency coordination. Most noteworthy of these include the cooperative activities between the Air Force Phillips Laboratory and Marshall Space Flight Center regarding rocket testing, the relationships between Sandia and Phillips Lab in the power and propulsion areas, and the sharing of facilities between Ames and Brooks AFB dealing with human and machine operations.

Figure 17 shows the total inventory size and distribution and those selected for analysis. The data for these key facilities were obtained as described previously in this report and in more detail in Volume 1.

With a knowledge of the facilities, concentration was placed on those facilities believed to be most likely to generate significant recommendations. The ability to satisfy future needs was analyzed using the mission and requirements model as described in Volume 3 and the facility inventory as described in Volume 1. The facility recommendations were then assembled using the same categories as described previously in the Space Operations section.

The 13 category 1A facility recommendations and implementation costs to effect the recommendations are summarized in Figure 18. These recommendations are aimed at improving efficiency with requiring a basic change in agency or facility roles and missions. Annual savings are probably understated as a degree of conservatism was applied in the costing analysis. In some cases cost savings were difficult to estimate because operating costs are frequently not associated with specific facilities. Key recommendations and their savings include the following:

- Consolidate the work performed at the 300 and 400 Area at White Sands Test Facility into the 400 Area ($1M/year).

- Reduce the number of national high pressure component (turbopump) test facilities from eight to no more than two. Do not fund improvements to current facilities until a decision is made on which facilities should be retained.

	INVENTORY				SELECTED FOR ANALYSIS				COMMENTS
	NASA	DoD	OTHER	TOTAL	NASA	DoD	OTHER	TOTAL	
POWER & PROPULSION	46	26	18	90	46	26	18	90	"OTHER" selected contains 4 DOE and 14 Industry Facilities.
INFO & COMM	59	21	104	184	43	11	103	157	"OTHER" categories both contain 1 DOE and 103 Industry Facilities.
HUMAN & MACH OPS	111	38	0	149	94	32	7	133	Inventory figures based on data available as of 10/1/93.
MAT. STRUC. & FLT DYN	86	22	124	232	84	19	1	104	"OTHER" inventory contains 11 DOE and 113 Industry Facilities. "OTHER" selected contains 1 DOE facility.

Figure 17. Total Inventory Size and Distribution

	NUMBER RECOMMEND.'S	TOTAL IMPLEM. COST - $M	ONE TIME SAVINGS/COST AVOIDANCE - $M	TOTAL ANNUAL SAVINGS - $M
POWER & PROPULSION	4	2	NA	36
INFO & COMM	3	75	NA	6
HUMAN & MACH OPS	1	2	NA	0
MAT, STRUC, & FLT DYN	5	37	4	4
TOTAL	13	116	4	46

Figure 18. Facility Recommendations and Implementation Costs (Category 1A)

- Consolidate all USAF Space Structures R&D facilities at Phillips Laboratory ($4M non-recurring cost).

- Develop a national facility, with industry participation, capable of high electron beam and x-ray processing/curing of composite materials. This facility leads to a 90% reduction in process cost for composite structures and places the U.S. in a competitive position with an existing French facility ($15M implementation cost).

- Maintain schedule for the Defense Nuclear Agency DECADE facility at Arnold Engineering Development Center.

- Downmode the A-1 and A-2 Test Positions at Stennis Space Center.

Category 2 facility recommendations are summarized in Figure 19. A number of facilities require further review to properly assess whether they are candidates for closure, upgrade, or consolidation.

The Category 2 recommendations offer additional opportunities for savings, but require additional actions prior to implementation. The more significant of these include the following:

- Conduct joint government/industry study to determine which 1 or 2 of the current eight High Pres-

	NUMBER OF RECOMMENDATIONS
POWER & PROPULSION	3
INFO & COMM	0
HUMAN & MACH OPS	4
MAT, STRUC, & FLT DYN	2
TOTAL	9

Figure 19. Category 2 Recommendations

sure Liquid Rocket Propulsion Component Test facilities should be optimized through selective upgrades and maintained in world-class condition.

- Determine appropriate size and location(s) of government facility(ies) to support hybrid rocket development testing.

- Conduct a joint government/industry study to recommend whether to reduce the number of active thermal vacuum chambers and/or to upgrade the remaining ones. Defer construction of any new thermal vacuum chambers pending this review.

- Study the construction of an acceleration facility to provide a central location for all hypergravity research.

The full Space Research and Development Task Group's recommendations for Category 1 and 2 facilities and a complete listing of Category 3 facilities are included in Volume 5 of this report. Recommendations relative to Hypersonic R&D facilities were addressed by the Aeronautics Task Group and are found in Volume 2 of the report. Major recommendations in Categories 1 and 2 are summarized in Figure 20 which depicts a timetable for implementing the recommendations or conducting supporting studies.

NFS SPACE RESEARCH AND DEVELOPMENT FACILITIES PLAN MATCHED TO MISSION AND REQUIREMENTS MODEL

△ CONSOLIDATIONS
○ UPGRADES

	YEAR									
	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03
POWER AND PROPULSION										
• CONSOLIDATIONS		△4 △5			△8					
• UPGRADES / NEW									○11	
INFO SYSTEMS & COMM										
• CONSOLIDATIONS	△1									
• UPGRADES / NEW			○6							
HUMAN & MACHINE OPS										
• CONSOLIDATIONS										
• UPGRADES / NEW	○2									○12 → 2010
MAT'LS, STRUCTURES & F.D.										
• CONSOLIDATIONS			△7		△9					
• UPGRADES / NEW	○3				○10					

NOTES:

1. Close JPL mirror refurbishment facility
2. Human-rate test facility at JSC
3. New microgravity aircraft
4. Consolidate WSTF 300/400
5. Deactivate SSC A-2
6. Complete AEDC DECADE
7. Consolidate USAF structures R&D
8. Deactivate SSC A-1
9. New cold optics facility
10. New E-beam composites R&D facility
11. Nuclear Thermal Propulsion Facilities
12. Advanced motion effects R&D center

Figure 20. Implementation Timetable

MAJOR RECOMMENDATIONS

AERONAUTICS

Two new wind tunnels should be constructed by 2002 for commercial jet transport development. Non-traditional approaches should be considered for obtaining this critically needed capability. Legislation patterned after the "Unitary Plan," which was enacted previously for commercially oriented wind tunnel acquisition, is one option. Tax incentives are another. Since the new capability is targeted so strongly toward industry needs, industry could have a much greater involvement in the venture.

Geographical location of the new wind tunnels merits careful consideration because they are expected to be in service for decades. A "level playing field" should be established to evaluate various locations on their technical merits with strong weighting of factors which help keep operating costs low.

SPACE

Seventy recommended options for improved effectiveness should be considered for implementation. They can be accomplished without significant roles and mission changes. ***The responsible organizations should review the NFS consolidation/closure findings in Volumes 4 and 5 and develop implementation plans for each option.*** Representatives from the NFS Task Groups will assist in the process as desired.

The government and aerospace industry can take additional steps to streamline and focus the Nation's space facilities in this austere budget environment.

National facility planning is clearly affected by national objectives which are being reshaped in recognition of the changing needs in defense and in the civil and commercial sectors. ***The need exists for a national vision and underlying policy for space.*** It was observed that during this period of dramatic downsizing of all participating departments and agencies, the roles and missions of the agencies as currently established has, in some cases, produced an overlap of functions and responsibilities. This was a limiting factor in defining some facility improvements or savings/de-commissioning. Nonetheless, the review concentrated on the best technical approaches and opportunities which might guide future strategic planning. The agency heads may want to jointly review overlapping functions and responsibilities to determine if and where greater efficiencies/cost reduction could result without impacting negatively on the agency missions.

The NASA/DoD/Commercial Mission and Requirements Model document should have long-term value for organizations developing strategic plans involving facilities and their usage. ***The mission model should be updated annually and made available to organizations involved in the planning process.***

GENERAL

- ***Facility pricing presents barriers***

Although charging policy variations did not have a first order effect on facility recommendations, facility charging policies merit a more systematic look than was possible in the current study. For example, charging policies for launch services need review because they influence private industry's decisions on use of government facilities. ***Facility pricing and practices of DoD, DOC, DOE and NASA should be the subject of an in-depth review with the objective of developing uniform policy that encourages the most cost-effective commercial and interagency shared use of U.S. Government facilities.***

- ***NFS Inventory should be utilized***

An up-to-date facilities database is needed when program and budget decisions are made. Effort should be made to collect data missing from NFS Database and thus maximize its value as a unique reference asset. ***The database should be institutionalized in a proper form and maintained by the affected agencies on a permanent basis for future reference by both government and, where appropriate, industry.*** The database will prove particularly useful to the organizations responsible for implementing the NFS facility disposition recommendations and will assist in making decisions regarding the need for facilities.

- ***Multi-agency facility coordination process is needed***

NASA, DoD and DOE agency-level processes should be modified to promote systematic assessment of cost-effective facilities utilization. Strengthened agency-level processes are needed to ensure consideration of inter-agency options for joint use, alteration, consolidation and/or closure. The National Facilities Study should be institutionalized by assigning a headquarters-level organization in each agency to be responsible for facility assessments and establishing a multi-agency coordination process for facility use and disposition.

Appendix A

TERMS OF REFERENCE

NATIONAL FACILITY PLAN DEVELOPMENT

I. BACKGROUND

The United States is increasingly challenged by advances in technologies that will affect its global competitiveness in virtually all economic sectors. Preeminent among these are advances in aerospace technology. These advances are paced by modern highly productive research, development, and operational facilities. Recognizing this situation, on November 13, 1992, the NASA Administrator initiated the development of a comprehensive and integrated long-term plan for future aerospace facilities. This integrated plan would be accomplished in partnership with other Government agencies, industry, and academia to ensure that the facilities are world-class and to avoid duplication of effort. He contacted top officials in the Departments of Defense, Energy, Transportation, Commerce, and the National Science Foundation inviting them to participate in the development of the plan and the appropriate working groups. The Administrator proposed an Oversight Group chaired by John R. Dailey, NASA Associate Deputy Administrator, with representation from DoD, DoT, DoE, DoC, and the NSF. Each of the agencies responded with nominations of individuals to serve on the Oversight Group and provide support on Task Groups to establish detailed plans. This Terms of Reference document provides the coordinated charter for development of the Aerospace Facilities Plan.

II. PURPOSE

To formulate a coordinated National Plan for world-class aeronautical and space facilities that meets the current and projected needs for commercial and Government research and development, and for Government and commercial space operations.

III. SCOPE

The plan will include a catalogue of existing Government and industry facilities that support aeronautics and astronautics research, development, testing, and operations. International facilities will also be catalogued to determine capability relative to U.S. facilities and applicability to address U.S. facility shortfalls.

The plan will include a requirements analysis which will consider current and future Government and commercial industry needs as well as DoD and NASA mission requirements, through the year 2023, and specifically will address shortfalls in existing capabilities, new facility requirements, upgrades, consolidation, and phase out of existing facilities. All new facility requirements and upgrades will be prioritized and detailed schedules and total funding will be specified. Joint management schemes, life cycle costs, and siting requirements will be fully evaluated.

Joint funding between agencies and Government/industry will be considered. Shared usage policies will be developed where nonexistent.

Costing, definitions, evaluation methodology and dollar threshold for facility inclusion in review will be approved by the Oversight Group.

IV. ORGANIZATION

An Oversight Group, chaired by NASA with a DoD Vice-Chairman and including membership from DoE, DoT, DoC and the National Science Foundation, will have responsibility for implementing this TOR and plan development. The secretary will be nominated by NASA.

The chairman will appoint a study director for executing this TOR. This person will be responsible for conducting the study and its schedule, coordinating participation, integrating all inputs, preparing the final products, and providing those products to the Oversight Group.

To assist the study director, four task groups will be established. These are the Aeronautics R&D Task Group, the Space R&D Task Group, the Space Operations Task Group and the Facilities Costing and Engineering Group. The task groups will be cochaired by NASA and DoD. All participating agencies will provide representatives to each task group. The task groups will have the authority to establish working groups to assist them in their tasks. Membership on the task and working groups will be limited to Government employees and participation is optional, except for NASA and DoD. The Aeronautics Task Group is an exception because of the special need to address commercial transport aircraft. For this reason experts from private industry participate as Special Government Employees, and the task group will function in accordance with the Federal Advisory Committee Act. Throughout the study, however, industry and academic inputs and advice should be actively solicited.

The Oversight Group will provide guidance to the task groups, serve as the coordination mechanism, perform periodic progress reviews, resolve disputes or misunderstandings that may arise between the agencies under the memorandum, and recommend an integrated plan for agency approval. The task groups will have responsibility for planning, directing, and providing recommendations in their particular discipline area.

Each agency will utilize its own reporting and tasking authority and will bear its and its employees' own costs for participation. Activities shall be subject to the availability of funds and personnel of each party.

V. PRODUCT

The study director will provide a summary report to the Oversight Group incorporating input from each of the task groups that includes a compendium of current facilities and capabilities; identification of shortfalls as a function of current and projected needs; and recommendations and rationale for new facilities, upgrades, consolidation, or closure of existing facilities. Recommendations will include cost impacts, either as investment costs or savings, and any other considerations that would bear on the decision (i.e., national security concerns, technology transfer, proprietary data rights, commercial competitiveness, etc.). The summary report will also include any recommendations relative to a policy nature, such as shared usage, common costing, and management and operation.

Upon approval by the Oversight Group, each report will be forwarded for agency approval. Final reports will be approved at the Deputy Administrator/Under Secretary level or equivalent. For the DoD, the responsible authority is the Under Secretary of Defense for Acquisition. Final reports should reflect a national viewpoint endorsed by NASA, DoD, DoC, DoT, DoE and NSF.

VI. SCHEDULE

Interim Task Group Reports (to support FY '95 budget decisions)	July 1993
Final Task Group Reports	January 1994
Oversight Approval - Task Group Reports	February 1994
Coordination of Individual Reports	March 1994
Approval of Individual Reports	March 1994

VII. APPROVAL, AMENDMENT, AND TERMINATION

This Terms of Reference shall enter into force upon the signature of all Parties and shall remain in force through July 1994. It may be modified, extended, or terminated by mutual consent of all parties.

Original Approved by:

Department of Commerce, David Barram, Deputy Secretary
Department of Defense, William J. Perry, Deputy Secretary
Department of Energy, Bill White, Deputy Secretary
Department of Transportation, Mortimer L. Downey, Deputy Secretary
National Aeronautics and Space Administration, Daniel S. Goldin, Administrator

Appendix B

PARTICIPANTS

OVERSIGHT GROUP

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Sally H. Bath, DOC
Dr. E. Fenton Carey, DOE
Dr. Wesley L. Harris, NASA/HQS
Jimmie D. Hill, DoD/USAF
James J. Mattice, DoD/USAF
Richard McCormick, DoD/USAF
Donald R. Trilling, DOT

TASK TEAM

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Charles R. Schilling, Assistant, NASA/HQS

Aero R&D Facility Task Group

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John V. Bolino, Co-Chair, DoD/OSD
L. Wayne McKinney, Exec. Sec., NASA/HQS
William S. Clapper, G.E. Aircraft Engines
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John E. King, McDonnell Douglas Aerospace
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Space Operations Facility Task Group

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Nancy Bray, Exec. Asst., NASA/KSC
Lt. Col. Laura Kennedy, Exec. Asst., DoD/USAF
Lt. Col. Stanley Mushaw, Exec. Asst., DoD/USAF
David W. Harris, NASA/HQS
Larry Heacock, NOAA
Samuel D. Malone, NASA/HQS
Richard W. Scott Jr., DOT
Ralph Spillinger, NASA/HQS

Facilities Costing & Engineering Task Group

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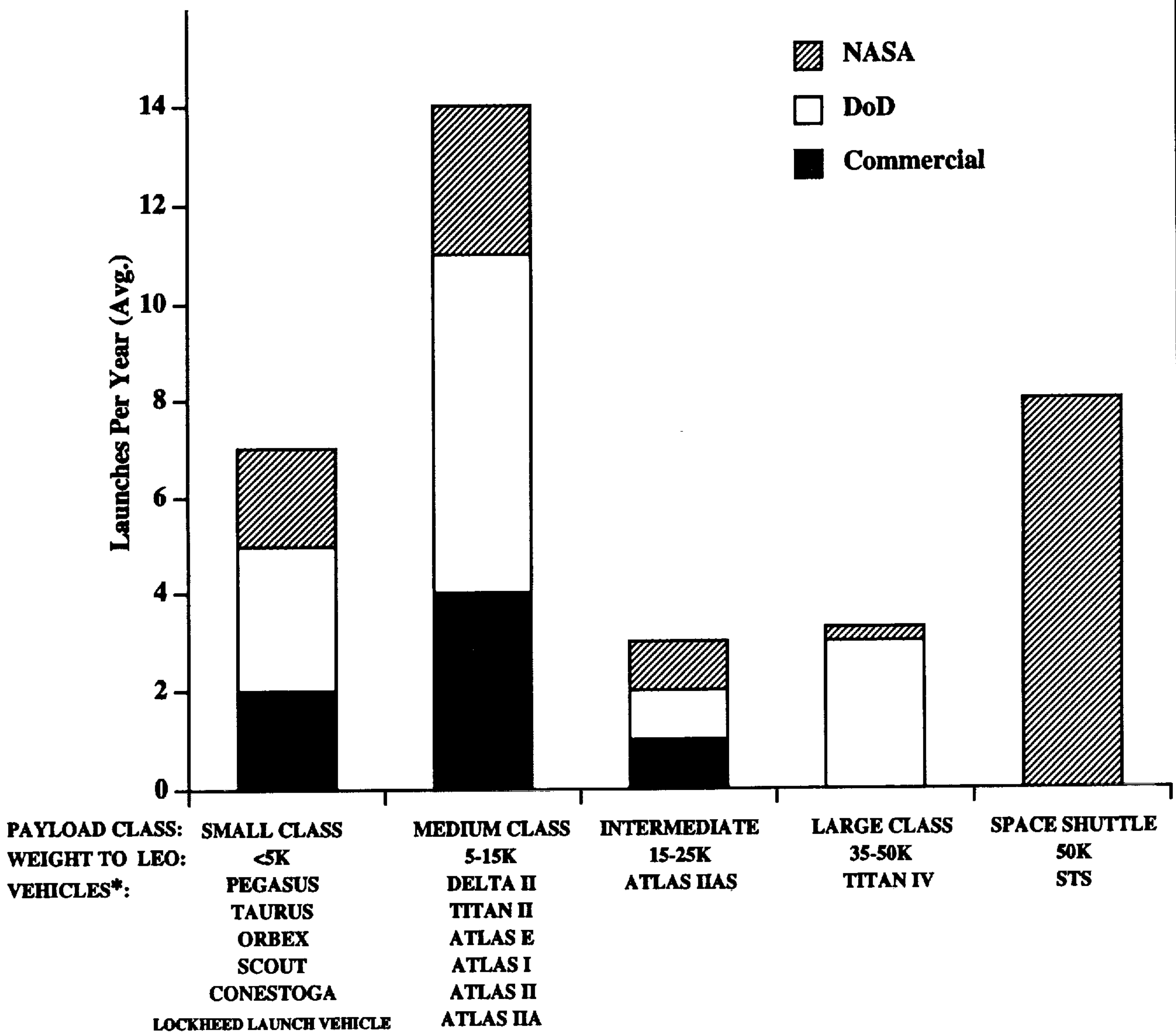
Billie J. McGarvey, Co-Chair, NASA/HQS
William W. Brubaker, NASA/HQS
Francis X. Durso, NASA/HQS
James Vitagliano, NASA/HQS

Working Group Members are identified in respective study report volumes. 1/31/94

Appendix C

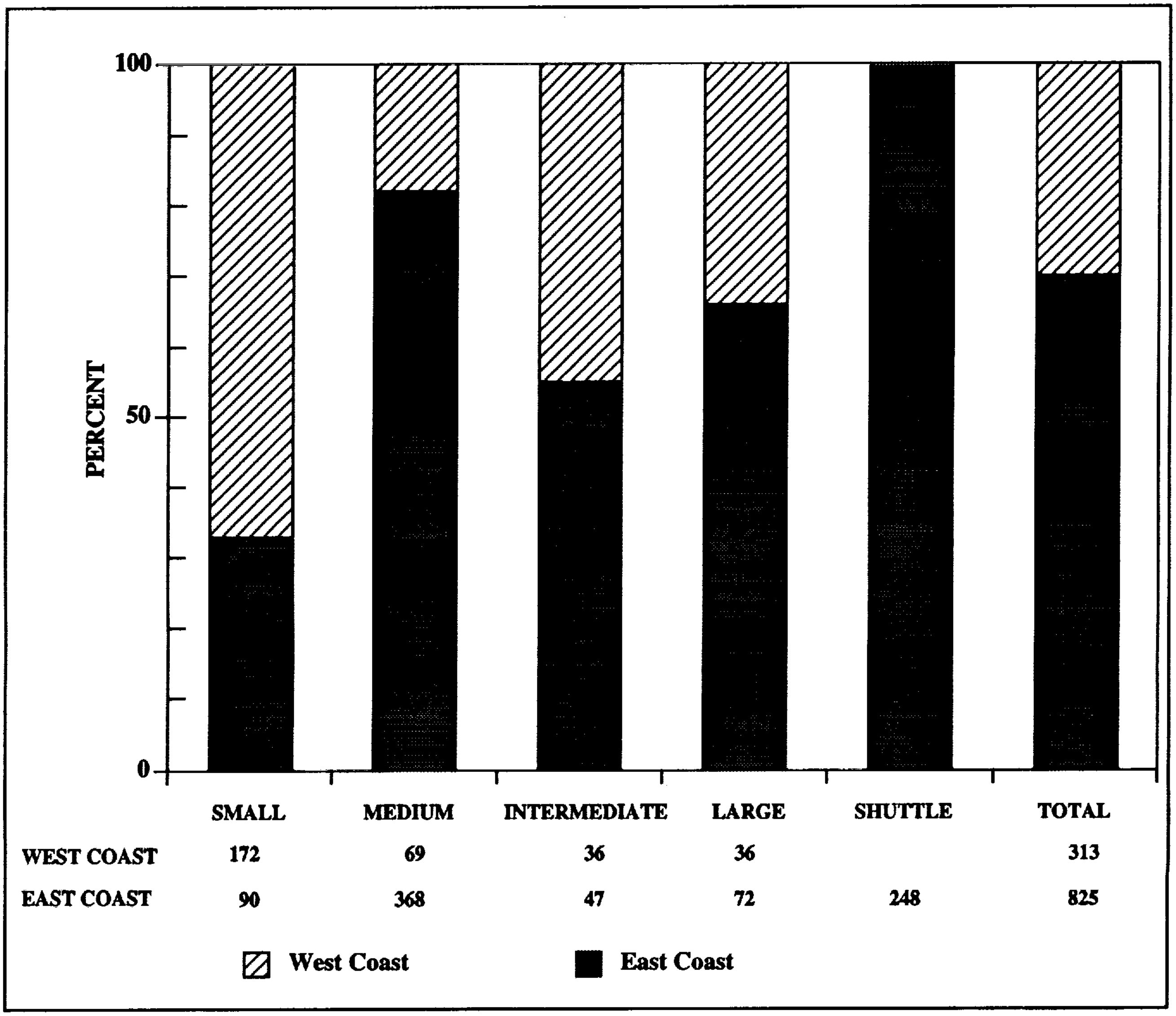
LAUNCH TRAFFIC PROJECTIONS

Figure 1. Space Launch Rates (through 2023)



* *PAYLOAD ASSIGNED BY WEIGHT CLASS TO EXISTING VEHICLES. DOES NOT IMPLY CONTRACTING DECISIONS.*

Figure 2. Launch Location (totals through 2023)



	SMALL	MEDIUM	INTERMEDIATE	LARGE	SHUTTLE	TOTAL
WEST COAST	172	69	36	36		313
EAST COAST	90	368	47	72	248	825

Appendix D

TERMS, ABBREVIATIONS AND ACRONYMS

ABM	Anti Ballistic Missile
AEDC	USAF/Arnold Engineering Development Center
AEDC ASTF	USAF/Arnold Engineering Development Center Aeropropulsion System Test Facility
AFB	U.S. Air Force Base
ARC	NASA/Ames Research Center
ATM	Atmosphere
CY	Calendar Year
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DNW	German Dutch Wind Tunnel (Netherlands)
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DRA	Defense Research Agency (British)
DSN	Deep Space Network
DSP	Defense Support Program
E-Bureau	Election Bureau
ELV	Expendable Launch Vehicle
EOS	Earth Observing Satellite
ETW	European Transonic Wind Tunnel (Cologne, Germany)
GE	General Electric
GEO	Geosynchronous Orbit
GFO	GEO Satellite Follow-On
GPS	Global Positioning System
HSCT	High-Speed Civil Transport
IRT	NASA/Lewis Research Center Icing Research Tunnel
KSC	NASA/Kennedy Space Center
LARC	NASA/Langley Research Center
LEO	Low Earth Orbit
MDC	McDonnell Douglas Corporation
NASA	National Aeronautics and Space Administration
NFS	National Facilities Study
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NTF	National Transonic Facility
O&M	Operations and Maintenance (Costs)
ONERA	French National Aerospace Agency
OPS	Operations
PT	Tunnel Pressure
PW	Pratt and Whitney
PWT	Pressurized Wind Tunnel
R&D	Research and Development
Re	Reynolds Number[1]
RSA	DoD Range Standardization and Automation Program
T	Transportation
TDT	Transonic Dynamics Tunnel
TOR	Terms of Reference
TWT	Transonic Wind Tunnel
T&E	DoD/Test and Evaluation
USAF	United States Air Force
UPWT	Unitary Plan Wind Tunnel[2]

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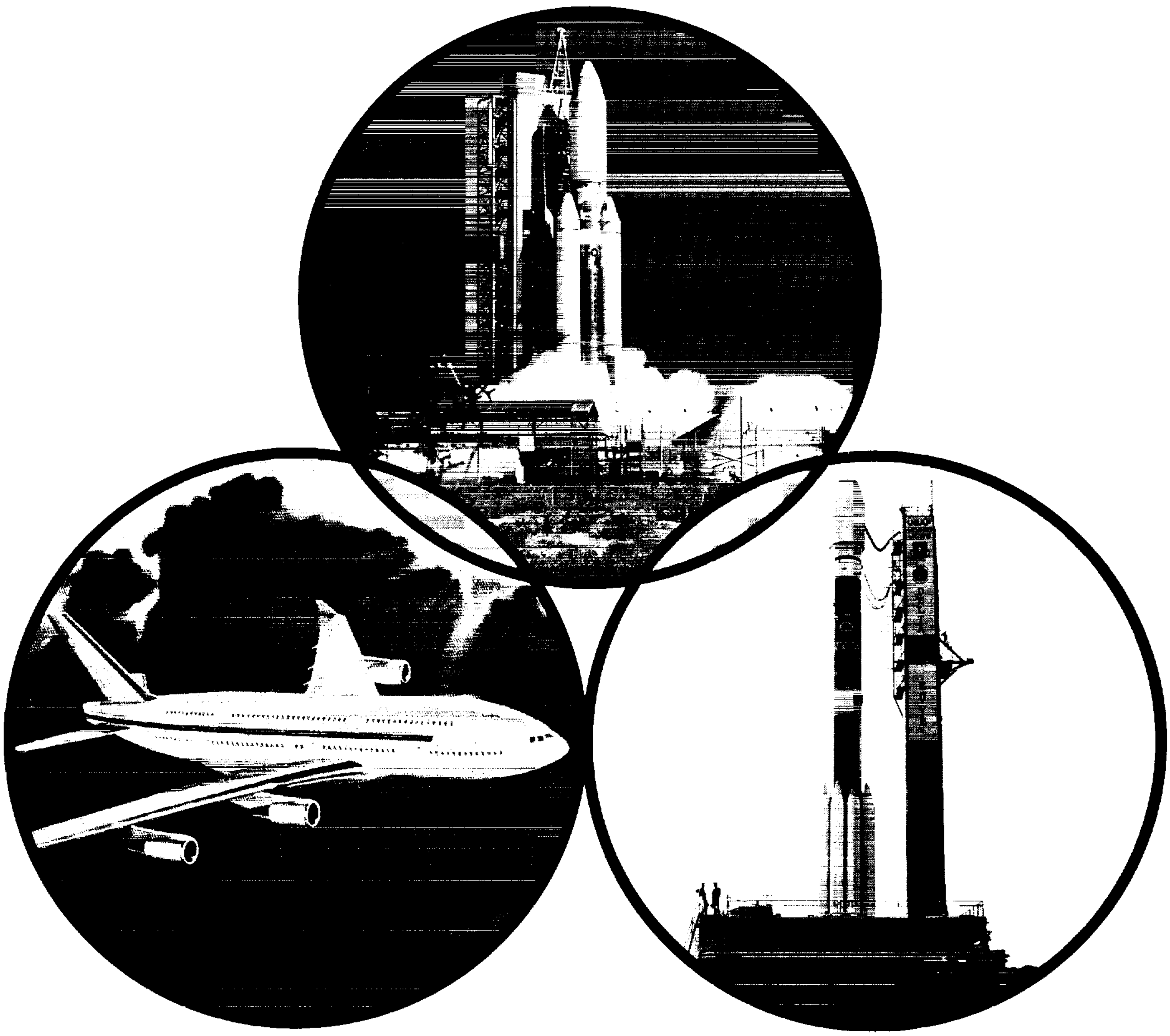
[1] Re, Reynolds Number = $\frac{\text{Reference Length x Velocity x Flow Density}}{\text{Viscosity}}$

[2] UPWT, Unitary Plan Wind Tunnel - A Congressional Act in 1949 provided for major wind tunnels at Ames, Langley and Lewis Research Centers to be staffed and operated by NACA (NASA) but available primarily to U.S. industry.

U.S. Aerospace Facilities

Space Research & Development



Aeronautics Research & Development

Space Operations

Government and Industry Contribute to Our Nation's Strength